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School of Civil and Environmental Engineering

The use of renewable energy sources for the HVAC demands of buildings



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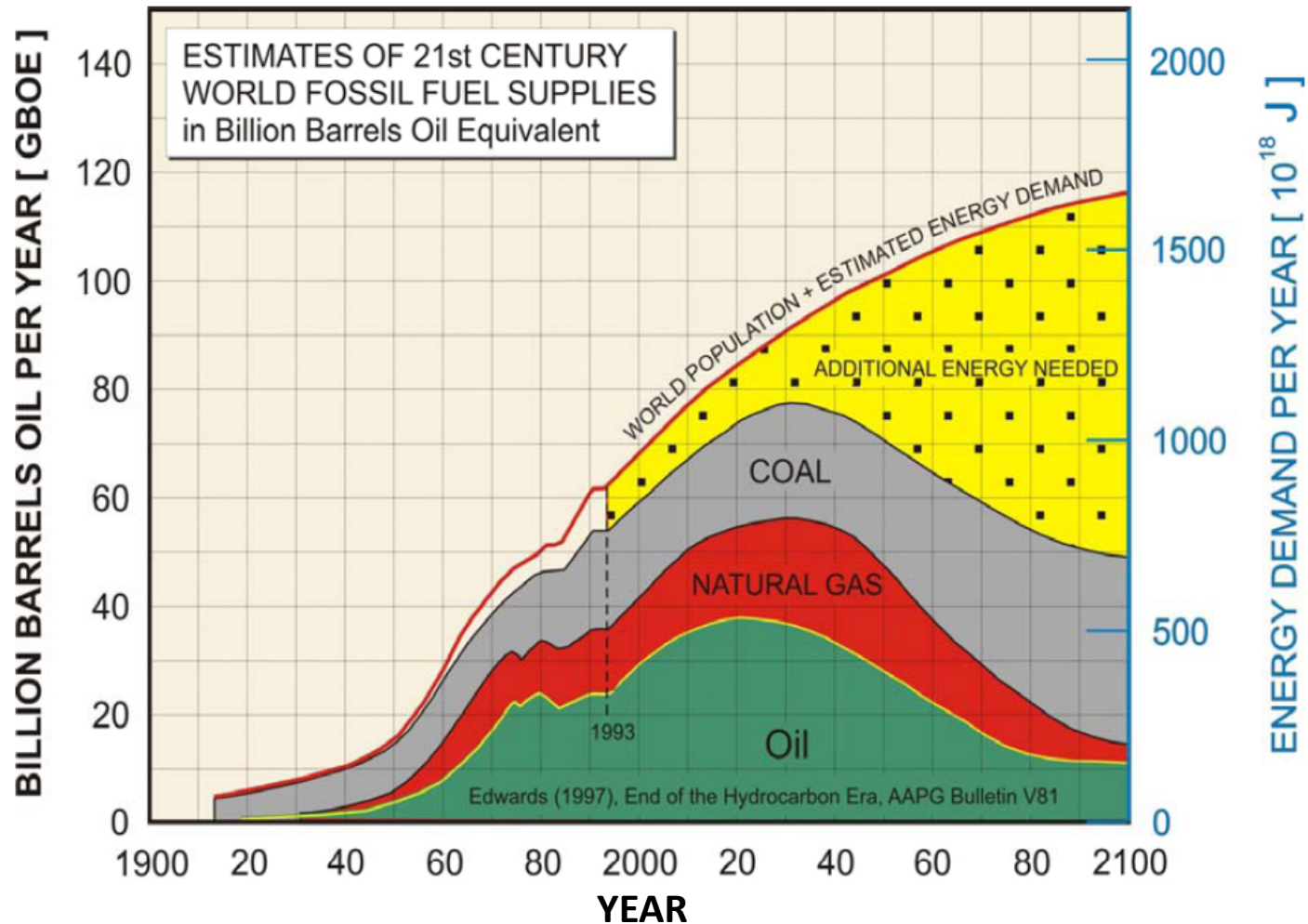
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- **OPPORTUNITIES - Renewable energy resources**
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CHALLENGES AND FACTS : Energy demand trends



➤ How to minimize our expenses (Eg. Importing oil...currency) ???

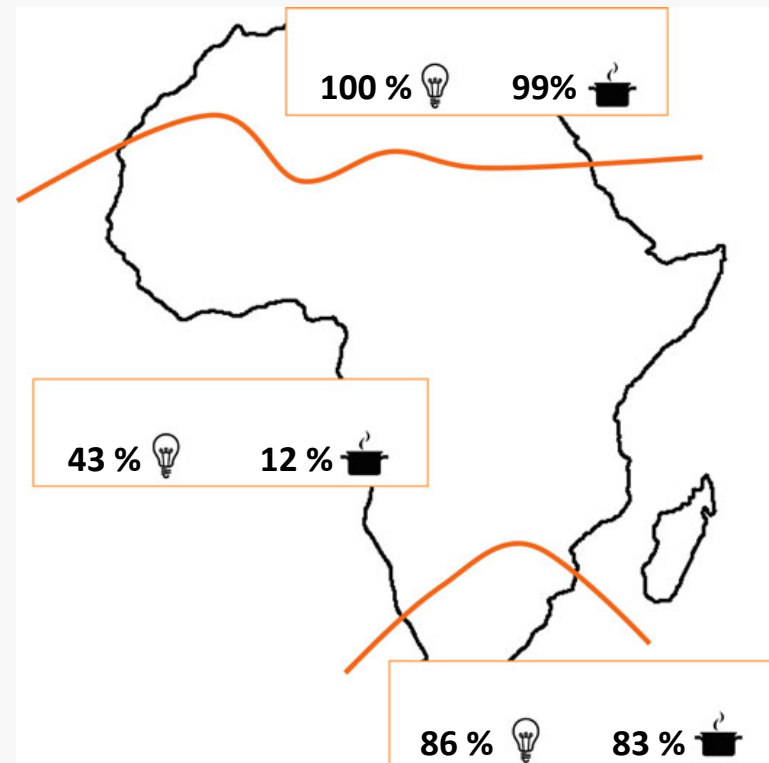


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CHALLENGES AND FACTS

Current energy consumption in Africa

- While countries in north and south Africa have very good access to electricity and clean cooking, two-thirds of SSA's population do not have access to power
- The trend in SSA will remain the same in 2050 as the population is expected to double by then.



Source: Hafner et al. (2017)

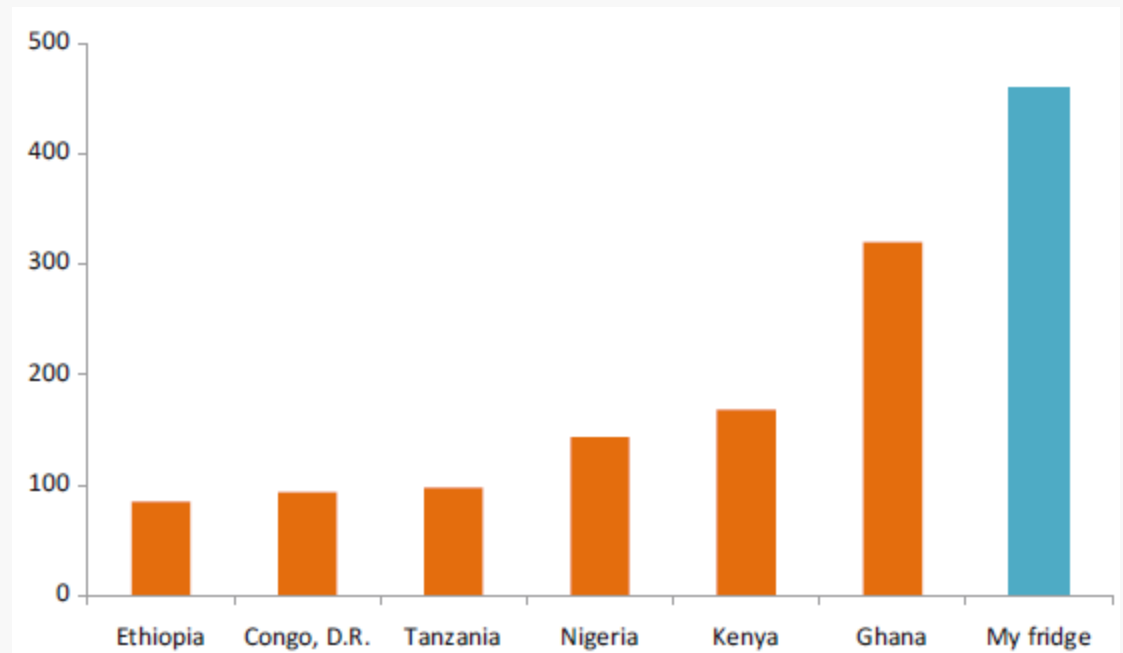


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CHALLENGES AND FACTS

Current energy consumption in Africa

“My fridge uses five times more energy than the average Ethiopian citizen (kWh)” quoted from Hafner 2018



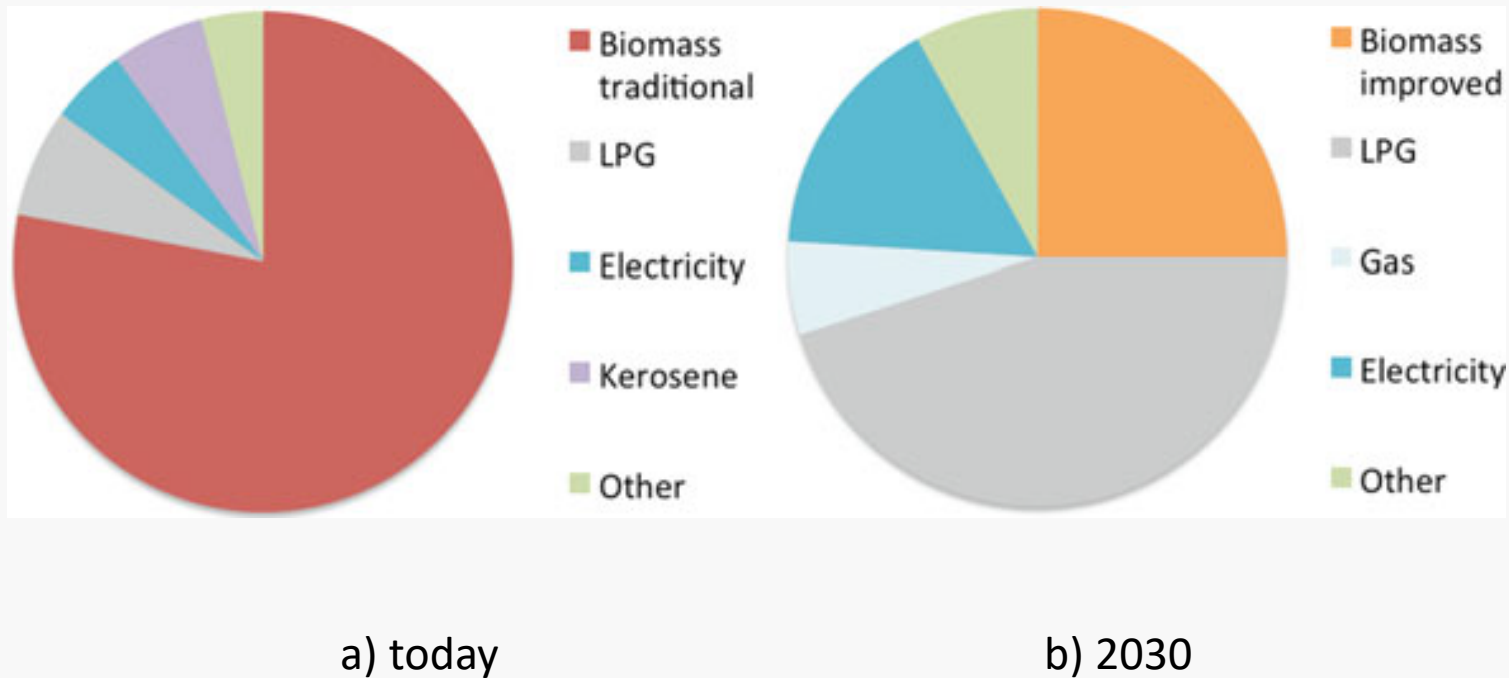
Source: IEA, World Energy Statistics, 2017



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CHALLENGES AND FACTS

Current energy consumption in Africa



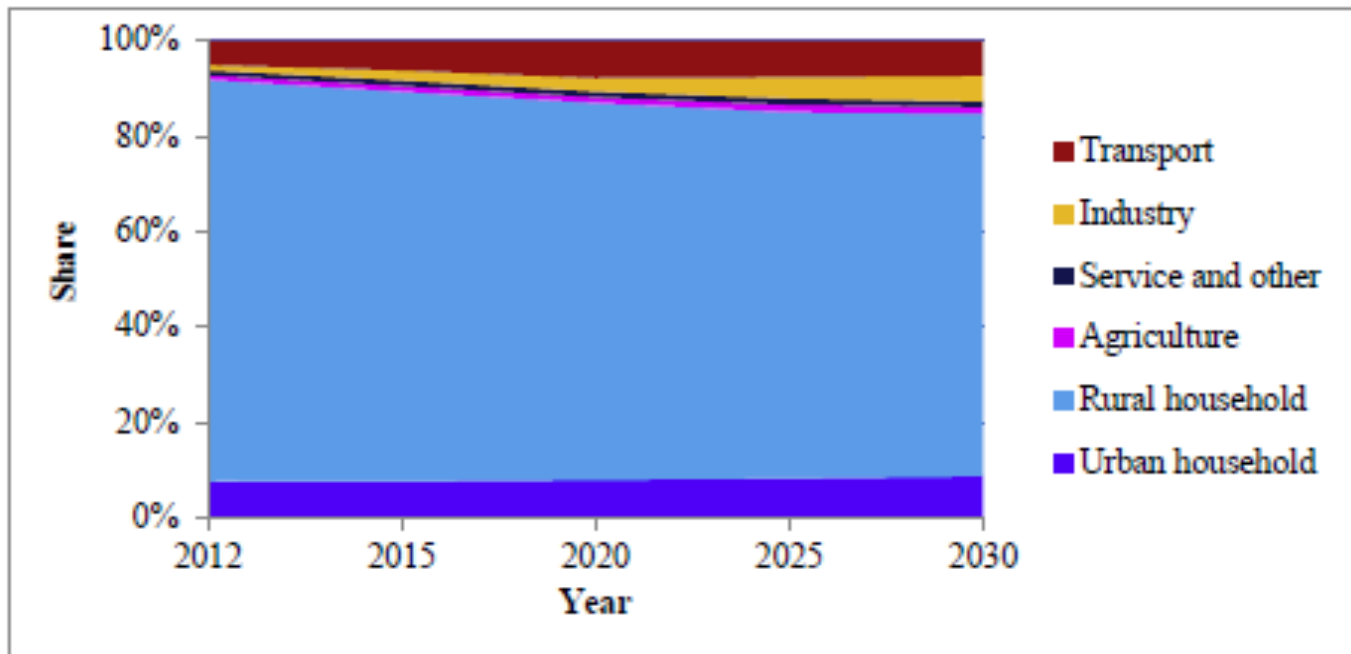
Source: Hafner et al. (2017)



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CHALLENGES AND FACTS

Energy consumption facts and prognoses : Ethiopia



Source: Mondal et al. (2018)

- It will be wise to think about alternative energy sources to cover the major demands of energy (households)
- Renewable energy sources are of the 1st choice!



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OPPORTUNITIES : Renewable energy resources

Renewable energy sources that are being used currently:

- Solar (Thermal / PV)
- Hydroelectric
- Wind turbines
- Biomass
- Geothermal heat pumps

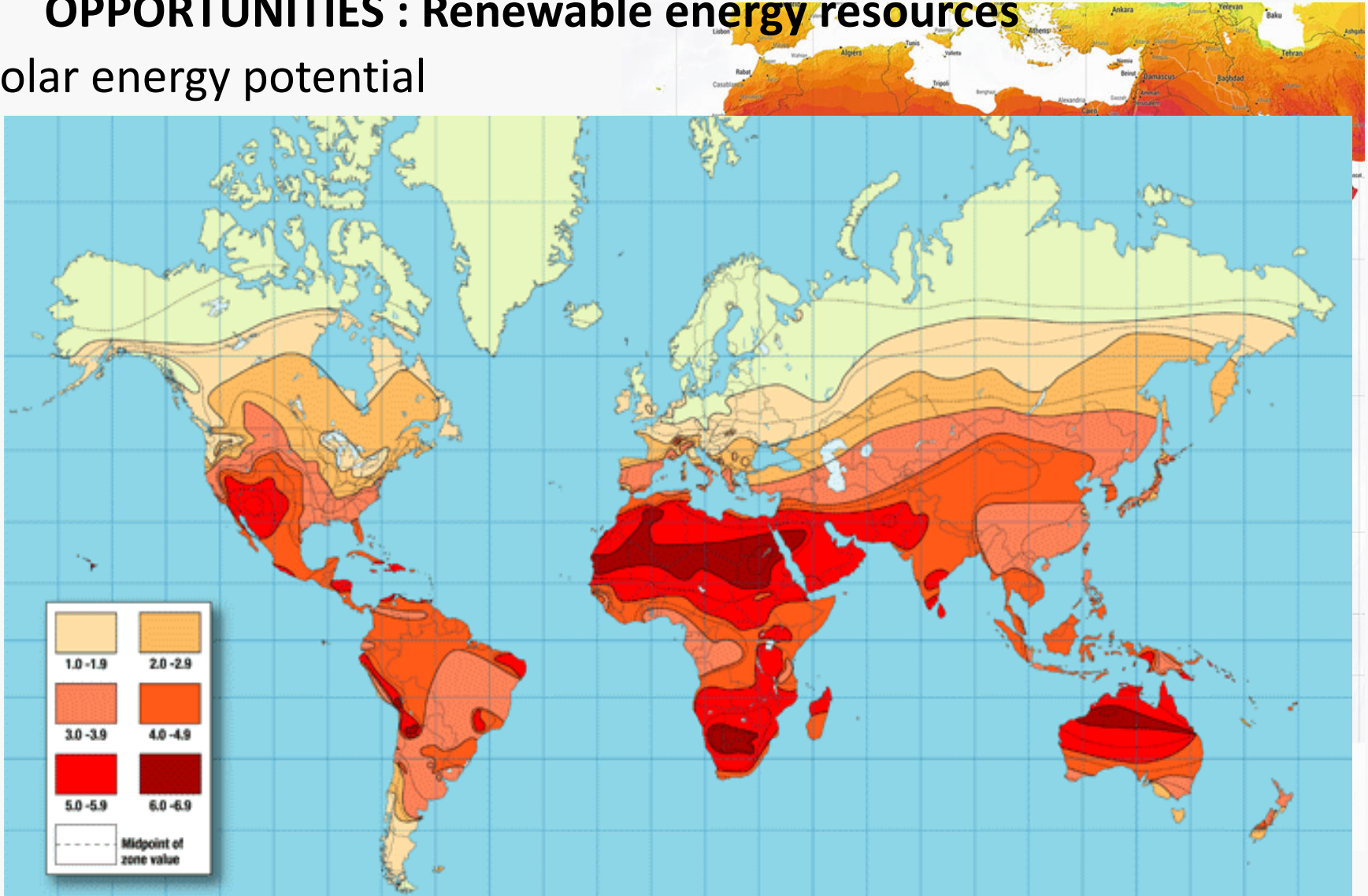




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OPPORTUNITIES : Renewable energy resources

Solar energy potential

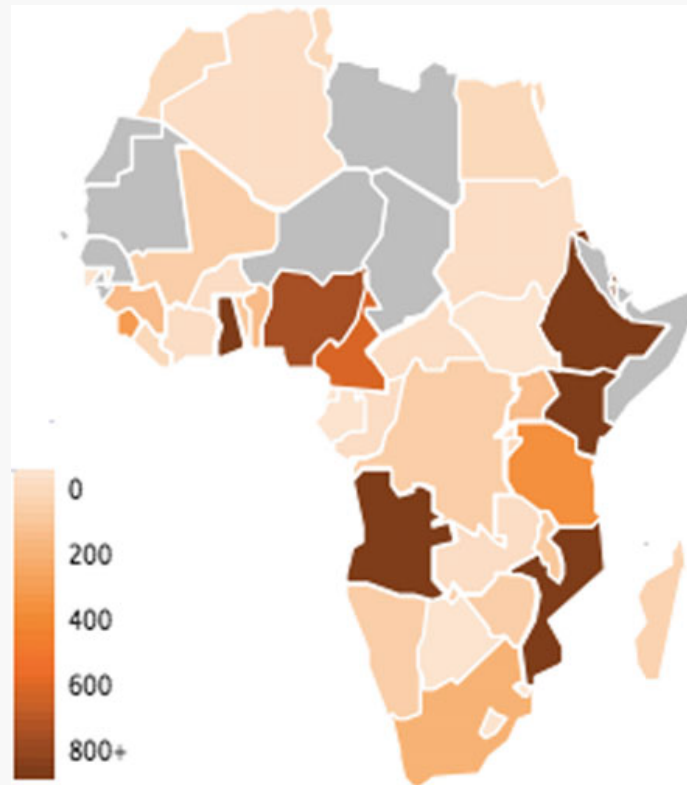




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OPPORTUNITIES : Renewable energy resources

Map of small hydropower potential (MW).



Source: The World Small Hydropower Development Report 2016.

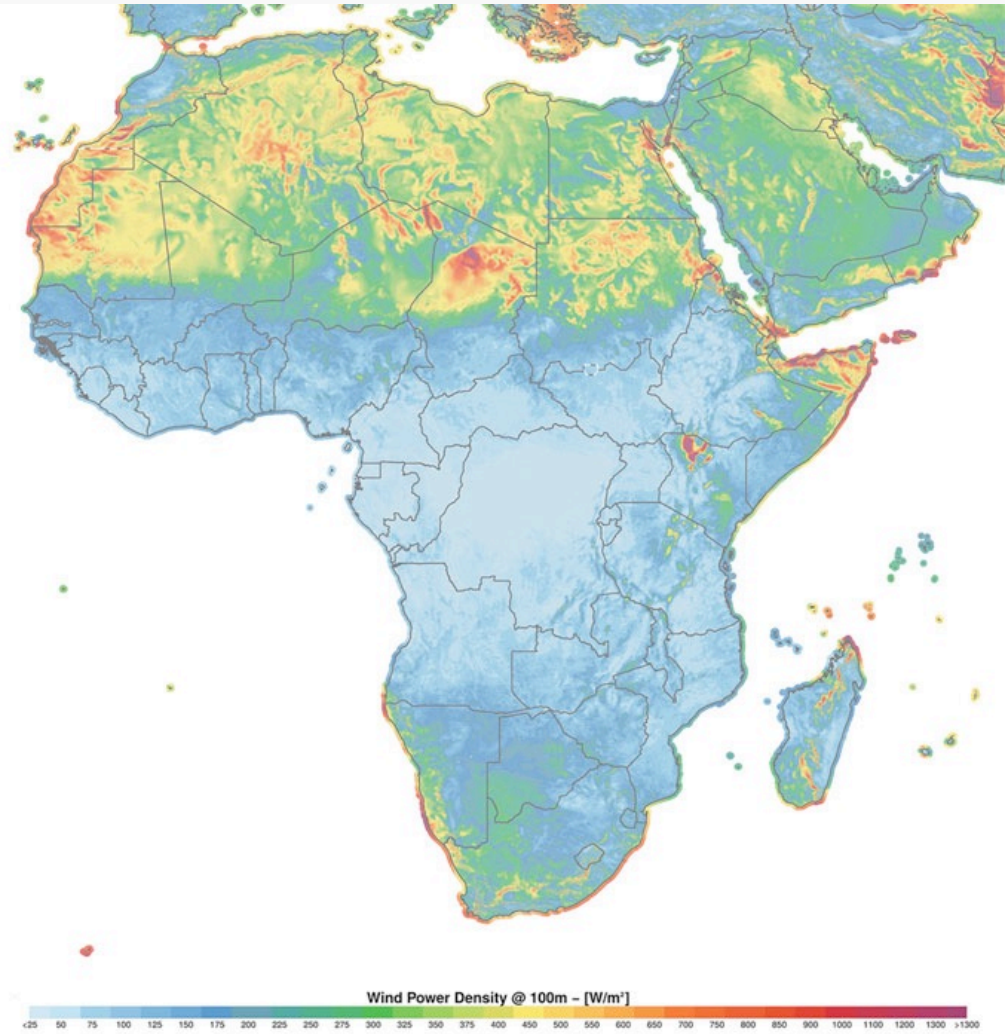


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OPPORTUNITIES : Renewable energy resources

Wind energy potential

Wind power density
(W/m^2) at 100 m
elevation.



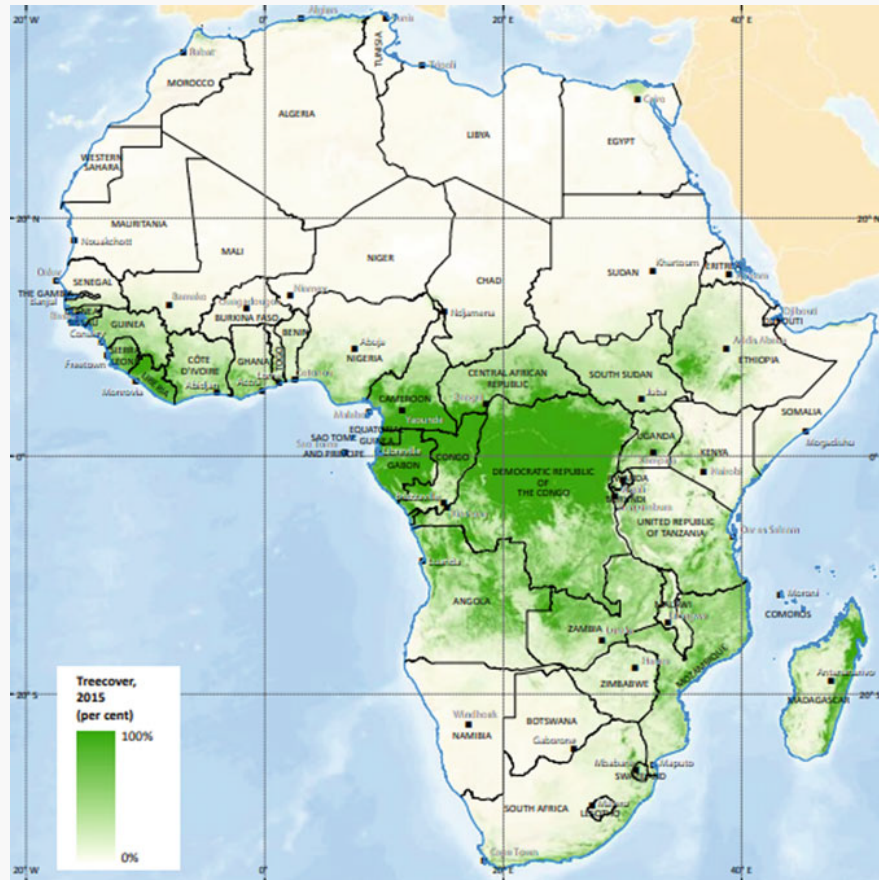
Source: Global Wind Atlas 2.0 (Technical University of Denmark 2017)



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OPPORTUNITIES : Renewable energy resources

Modern Biomass potential



Source Atlas of Africa energy resources (African Development Bank et al. 2017)



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OPPORTUNITIES : Renewable energy resources

Geothermal potential sites
in East Africa



Source: Atlas of Africa energy resources (African Development Bank 2017)

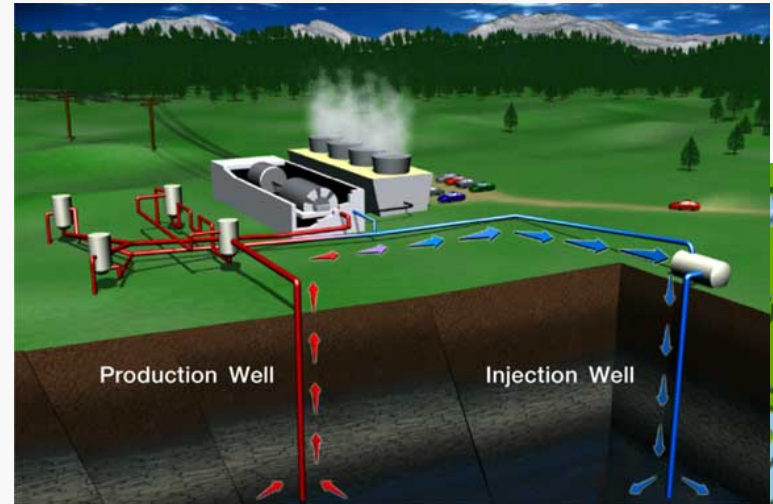


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OPPORTUNITIES : Renewable energy resources

Deep Geothermal (~ 5,000°C)

- Red Sea and East African rift valley:
Kenya, Ethiopia, Uganda,
Tanzania, Eritrea, Djibouti,
Zambia
(high geothermal Potential)
- Mediterranean sea:
Tunisia, Morocco, Algeria
(Potential for direct use)



Surface Geothermal

- HVAC for Buildings
(heating and cooling)
- Seasonal energy storage (climate control)

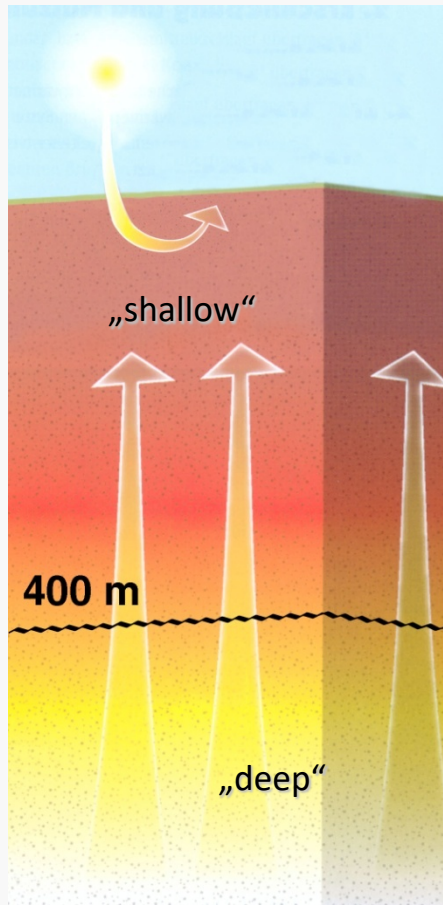




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OPPORTUNITIES : Renewable energy resources

Shallow Geothermal energy

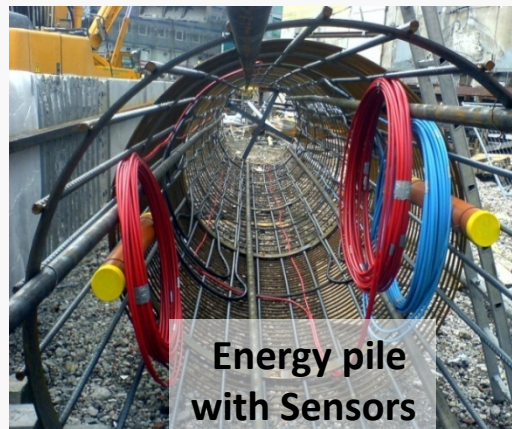


Elements of geothermal consumption:

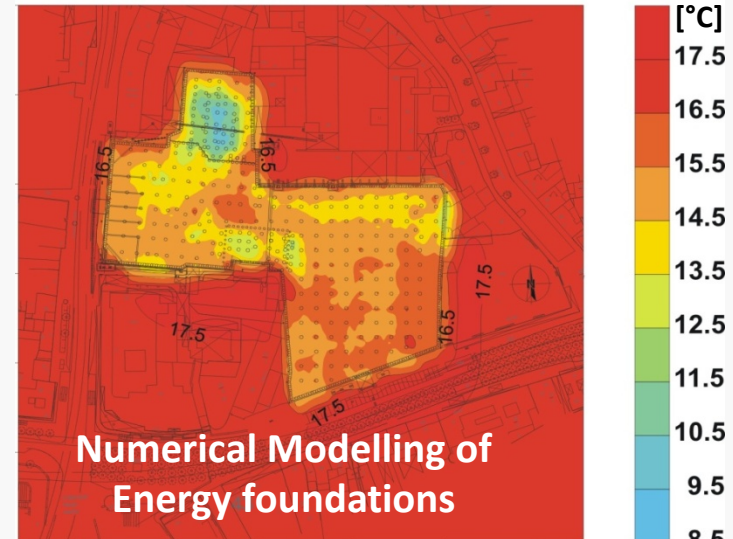
- Energy geo-structures
- Heat exchangers
- Heat pumps
- Equipment to measure and control



Construction of Energy piles



Energy pile with Sensors



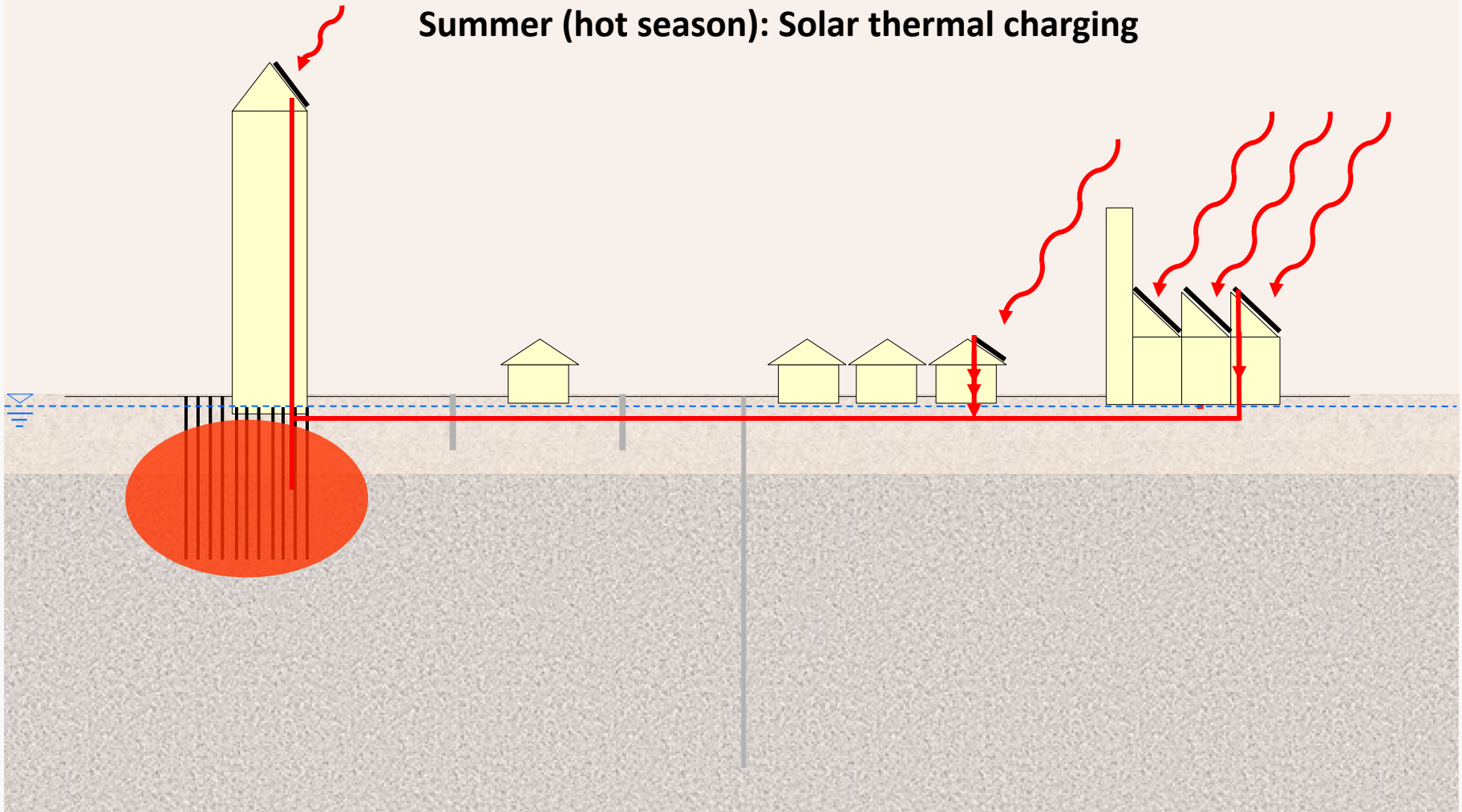
Numerical Modelling of Energy foundations



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OPPORTUNITIES : Renewable energy resources

Summer (hot season): Solar thermal charging

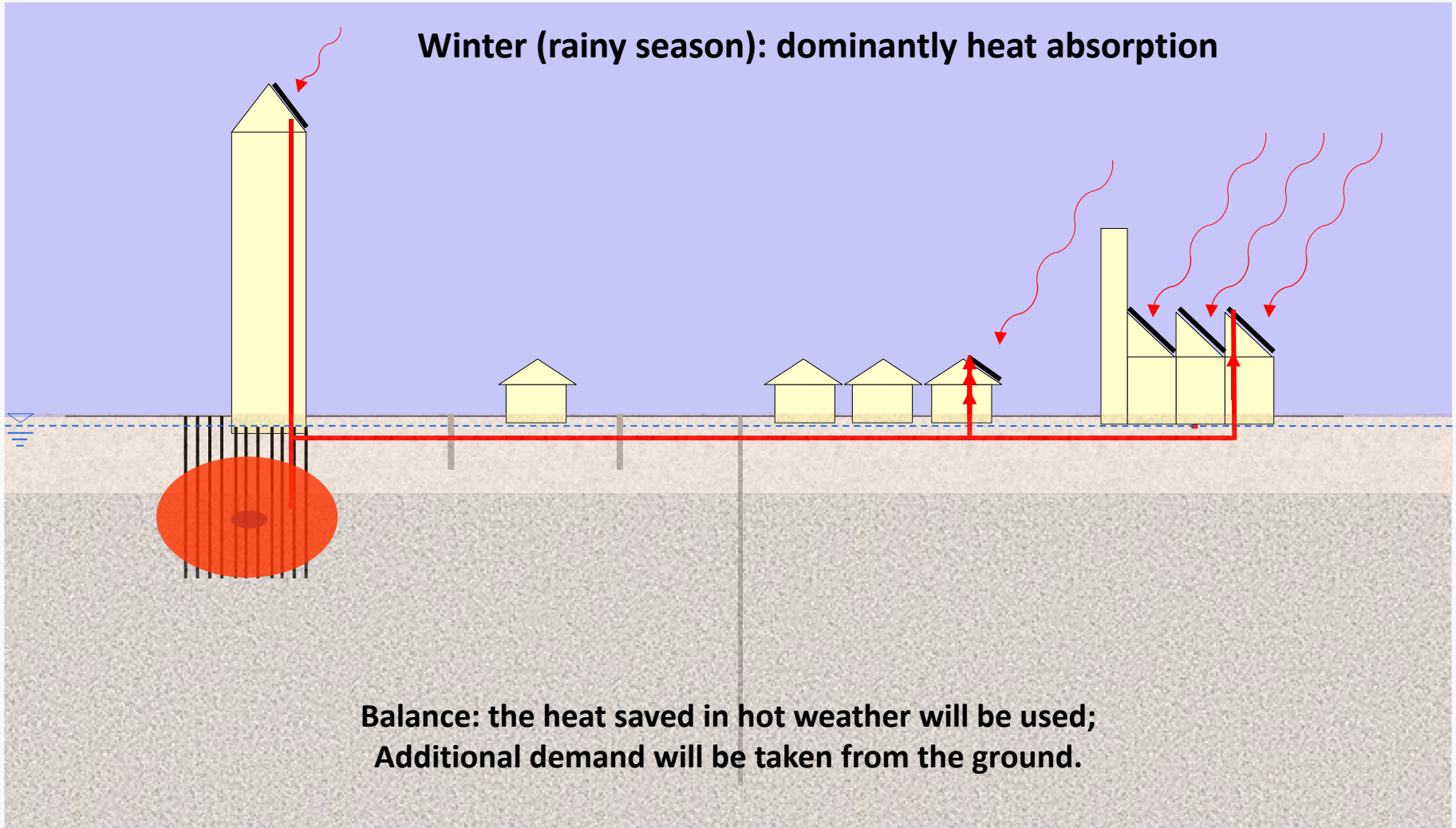




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OPPORTUNITIES : Renewable energy resources

Winter (rainy season): dominantly heat absorption



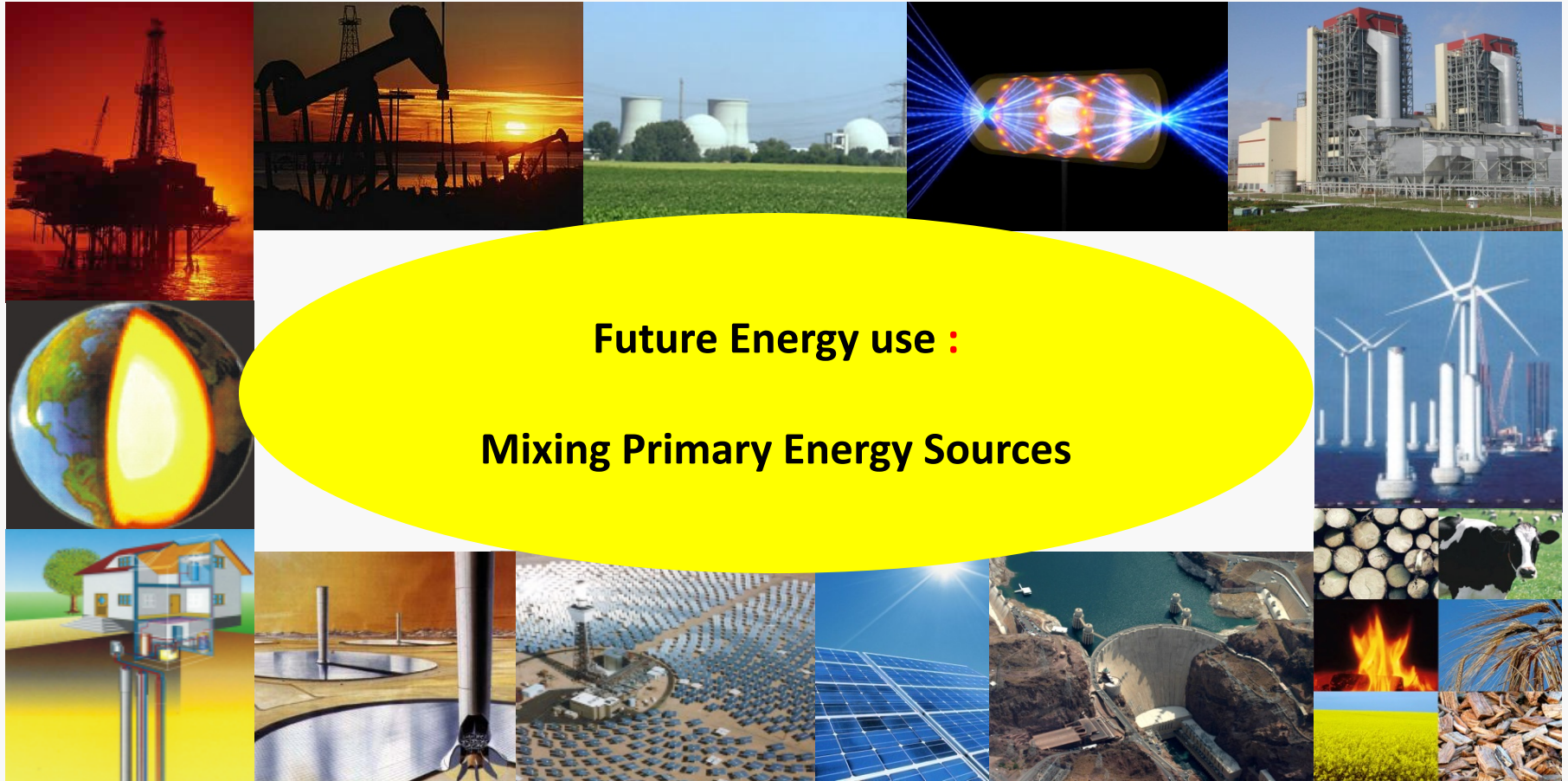
**Balance: the heat saved in hot weather will be used;
Additional demand will be taken from the ground.**



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PROSPECTS : World trends

Combining Energy Sources



Source : Katzenbach et al. 2010



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PROSPECTS : World trends

Smart Grids





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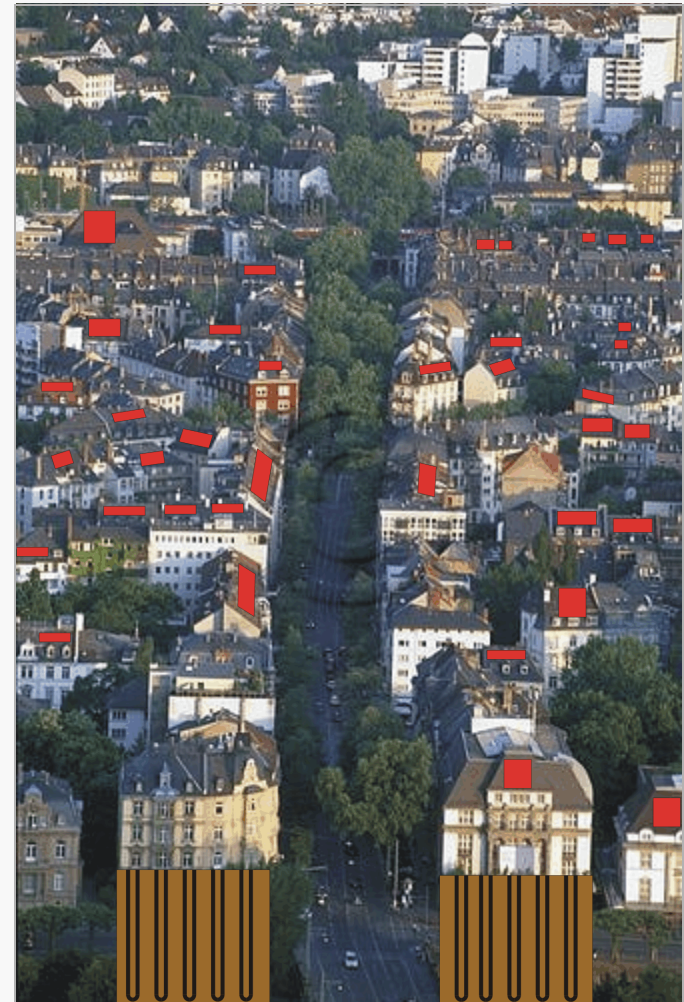
PROSPECTS : World trends

Combining different energy sources

- Can assure continuous energy supply, especially during weather changes, or fluctuations in one of the energy sources.
- Energy savers can couple the demand and consumption with time

Frankfurt am Main-Sachsenhausen

Source : Katzenbach et al. 2011

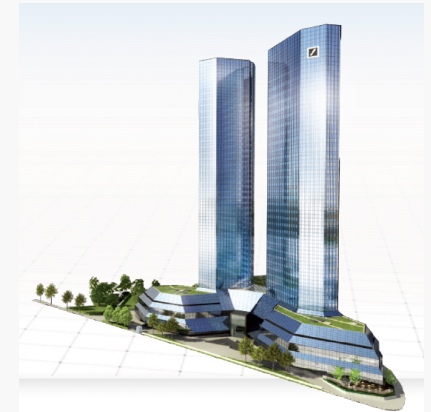




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PROSPECTS : World trends – Deutsche Bank / Green towers

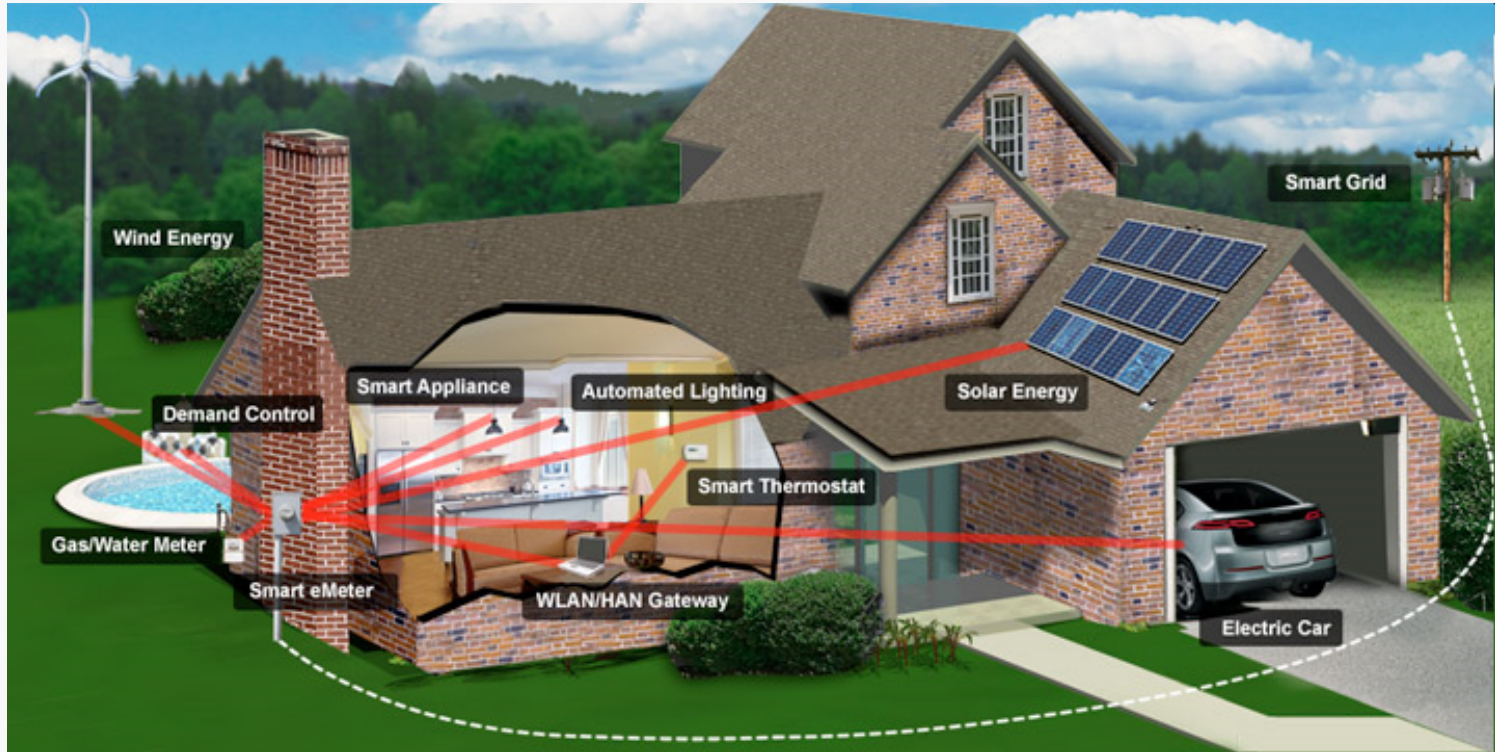
89% CO₂-Reduktion!





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PROSPECTS : World trends



Source : TI.com

Modern buildings with energy saving possibilities

- Smart Grids
- Smart metering
- Intelligent buildings



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PROSPECTS : Ethiopian buildings

Assessment of energy demands (total/ HVAC) of four high rise buildings in A.A.

Building	Storey	Basement	Area (m²)	Total energy Demand (KVA)	HVAC Energy Demand (KVA)	% <u>HVAC Demand</u> Total Demand
United bank	32	4	3,338	2,698.00	761.44	28.22
Zemen Bank	31	3	2,304	2,435.96	661.25	27.15
Wegagen Bank	23	4	1,800	1,329.00	359.69	27.06
Nib Bank	33	4	2,800	2,726.12	801.50	29.40

Experience: 20 – 30 % of total energy demands goes for HVAC



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PROSPECTS : Ethiopian buildings

Assessment of satisfying the HVAC demands of United Bank building in A.A.

Total Number of piles	282	For $D > 0.6$ m, extraction of 35 W per m^2 earth- contact area
Spacing (m)	2.40	
Length(m)	28.00	
Contact Area of pile (m^2)	70.37	
Diameter (m)	0.8	

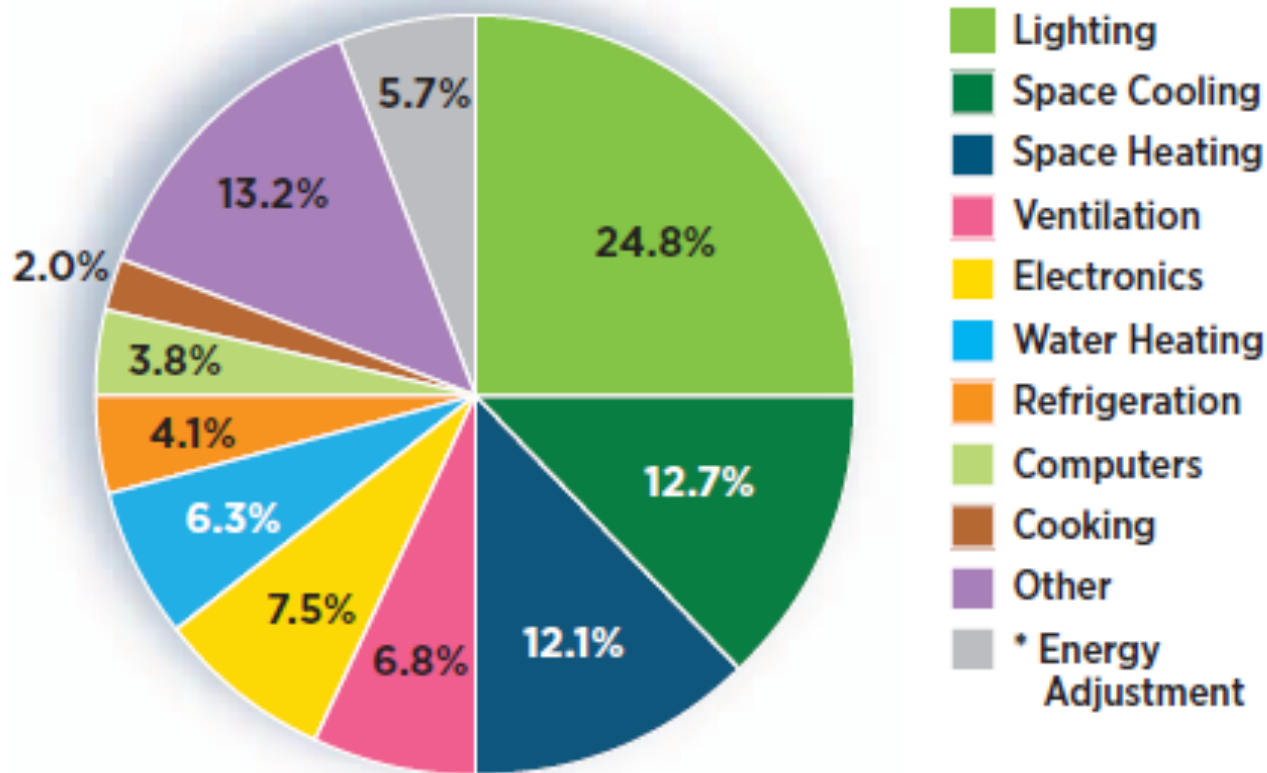
No. of Energy Piles	% Energy Pile/ Total No. Piles	Total Contact Area (m^2)	Amount of energy extracted (kW)	Energy required for HVAC system (kW)	% <u>Extracted</u> Required
50	17.73	3518.58	123.15	609.15	20.22
75	26.60	5277.87	184.73	609.15	30.33
150	53.19	10555.74	369.45	609.15	60.65
200	70.92	14074.32	492.60	609.15	80.87
249	88.30	17522.53	613.29	609.15	100.68



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PROSPECTS : HVAC of buildings

HVAC energy consumption



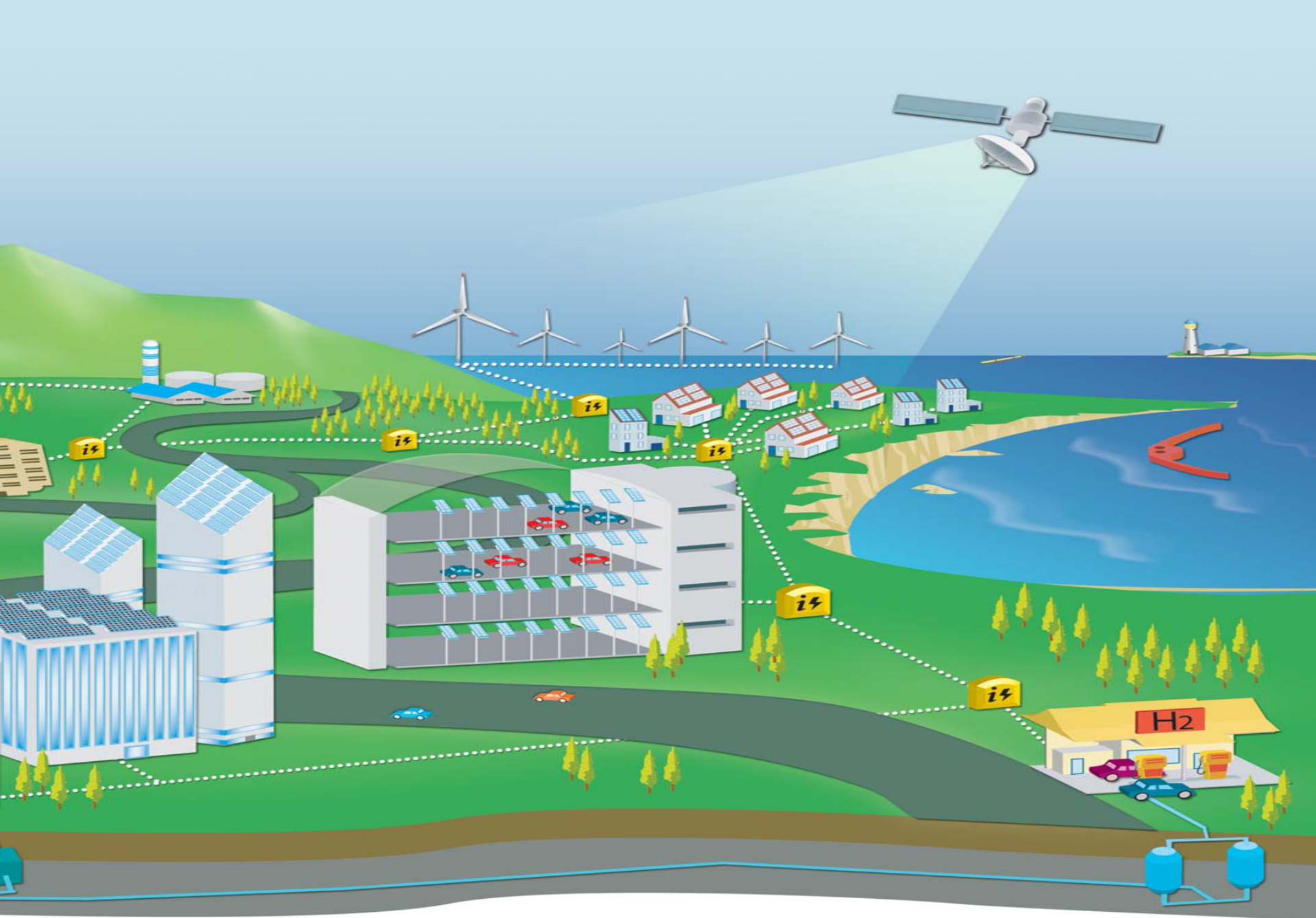
Source: 2009 Buildings Energy Data Book, U.S. Department of Energy, Table 3.1.4
http://buildingsdatabook.eere.energy.gov/docs/xls_pdf/3.1.4.pdf



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SUMMARY

- **For the ever increasing demands of buildings' energy, the use of renewable energy sources is a vital alternative.**
- **While hydropower took the lion's share of energy supply for Ethiopia its variability calls for other renewable resources like solar and geothermal energy sources, which are potentially ample.**
- **Renewable energy resources can be used to satisfy the HVAC requirement of buildings in Ethiopia, which is about 30 % of the total demands of buildings.**
- **Application of shallow geothermal energy for buildings helps CO₂ reduction / avoid climate change, in addition to cost minimization.**





**Thank you for
listening!**

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