Thematic Session 6: Emerging Low-Carbon Cooling Practices and Technologies

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Low Energy Cooling Technologies

11h45, September 16, 2022

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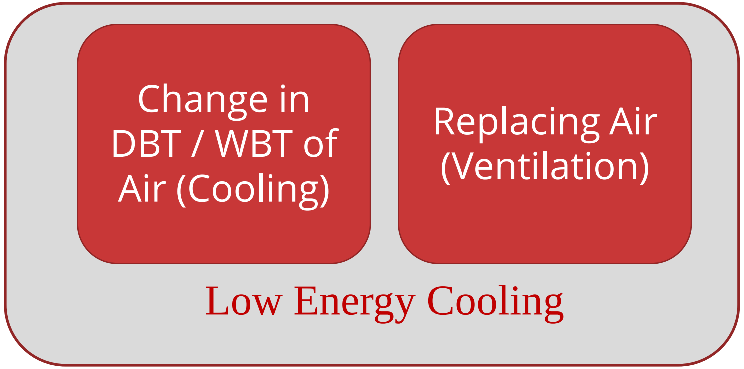
Introduction: Low Energy Cooling Systems



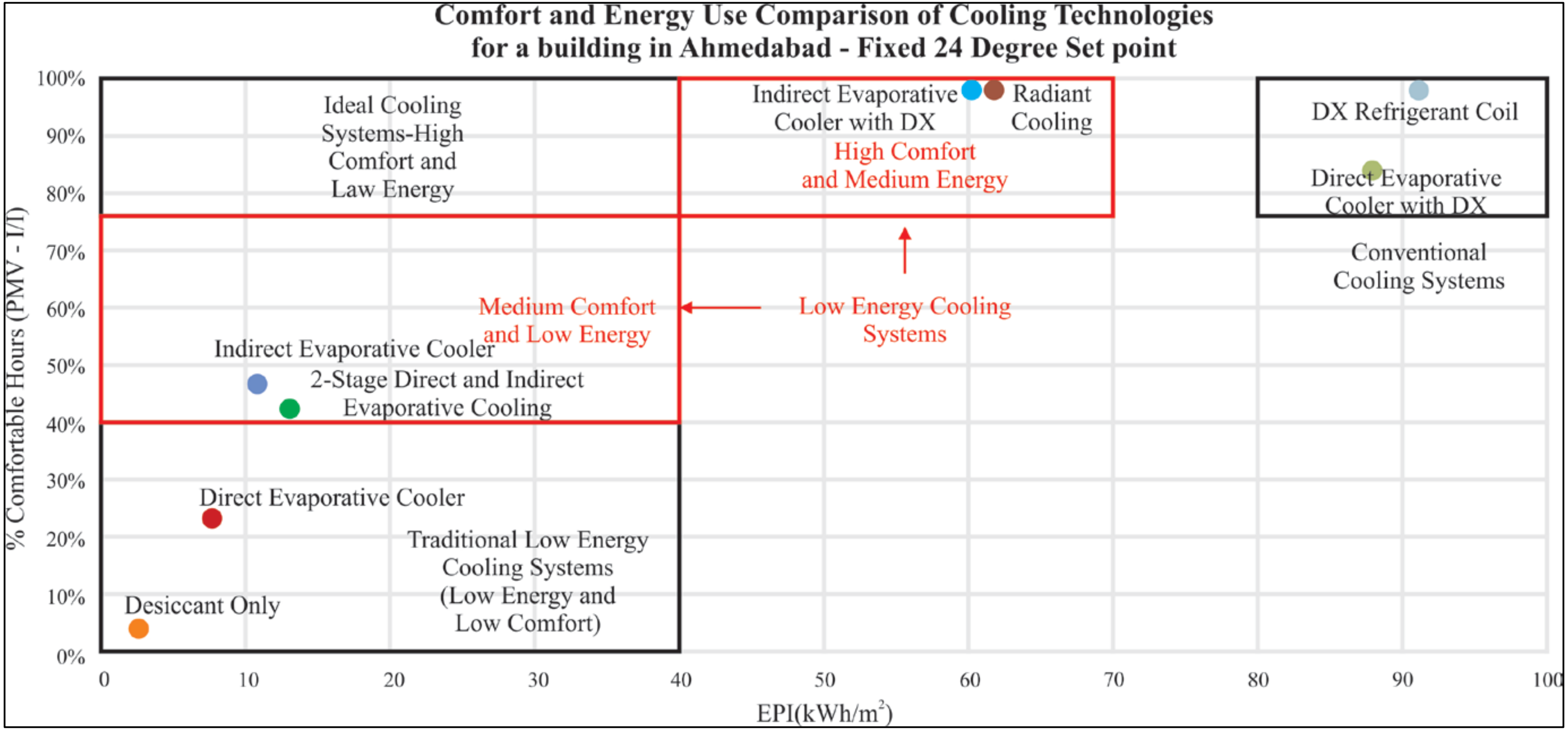
- No commonalty, scientifically accepted definition

- Loosely defined as
  - No Vapor compression cycle
  - Water as a refrigerant
  - Less energy consumption
  - No Global Warming Potential Chemicals
  - No refrigerate cooling/heating

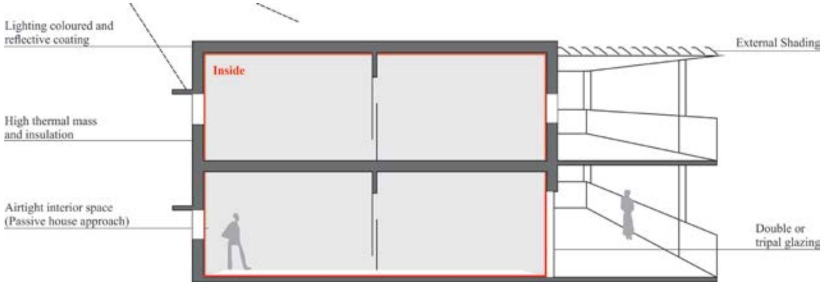
Sometimes includes
- Night Cooling with Mechanical Ventilation
- Ground – Aqua Coupled Cooling

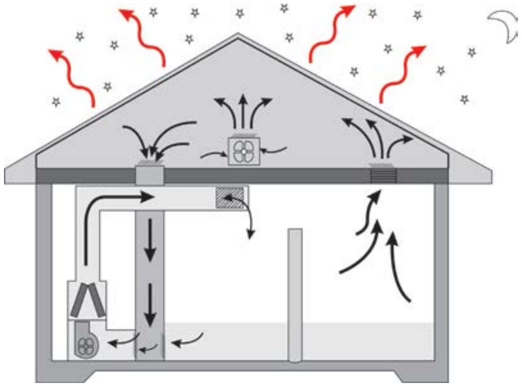
Source: Rawal, R., Shah, A., Shukla, Y., Ranjan, A., Jani, M., Pandya, H., (2018). Low Energy Cooling products, technical potential and market analysis. Ahmedabad: Centre for Advanced Research in Building Science and Energy

Current Status of Low Energy Cooling Systems



Cooling by Ventilation: Low Energy Cooling Systems





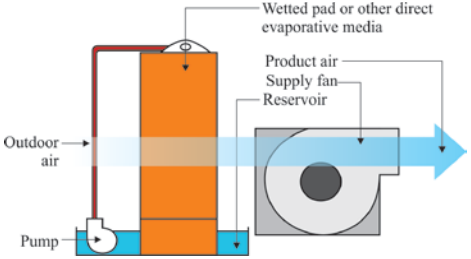
- **Favorable Factors**
  - Low night time temperature
    - Minimal solar loads
  - Low or no energy use

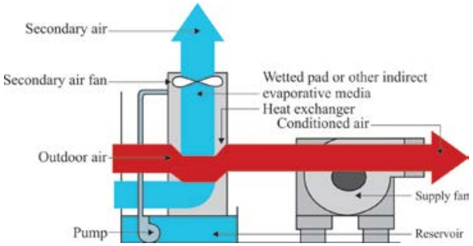
- **Unfavorable Factors**
  - High humidity
  - Limitations on cooling delivery
  - Deep floorplan plates – Natural ventilation

Source:
Program for Energy Efficiency in Buildings. (2020, August). BETTER DESIGN FOR COOL BUILDINGS. Retrieved from https://www.peeb.build//imglib/downloads/PEEB_Cool%20Buildings_Working%20Paper_August%202020.pdf
Nwaigwe, K. N., Anthony, O. C., Ogueke, N., Ugwuoke, P. E., & Anyanwu, E. E. (2012). Transient Analysis and Performance Prediction of Nocturnal Radiative Cooling of a Building in Owerri, Nigeria. Retrieved from https://www.researchgate.net/publication/274066021_Transient_Analysis_and_Performance_Prediction_of_Nocturnal_Radiative_Cooling_of_a_Building_in_Owerri_Nigeria

Evaporative Cooling: Low Energy Cooling Systems

- Evaporative Cooling
  - Direct Evaporative Cooling (DEC)
  - Indirect Evaporative Cooling (IEC)
  - Combined Evaporative Cooling (IEC/DEC)



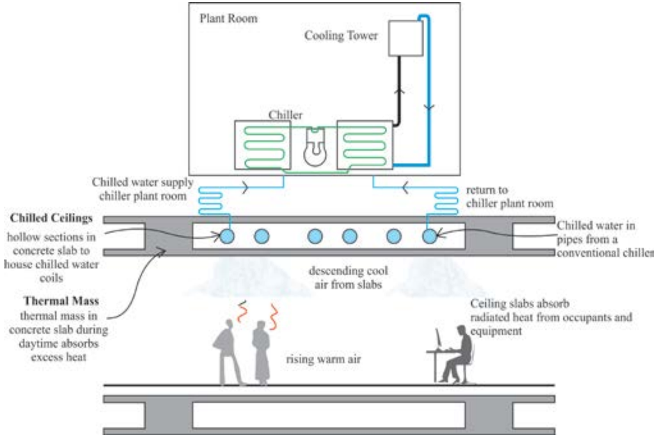


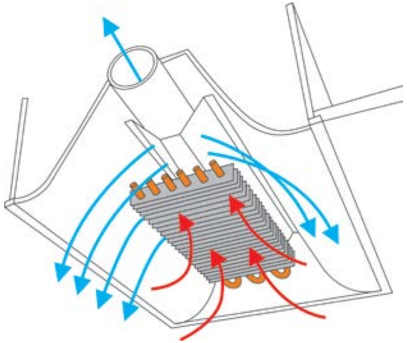
- **Favorable Factors**
  - Effective in dry climate
  - High air exchange rates
  - Low energy use
  - Hybrid design

- **Unfavorable Factors**
  - Humid climate
  - Water consumption – DEC

Source: Kanzari, M., Boukhanouf, R., & Ibrahim, H. (2013). Mathematical Modeling of a Sub-Wet Bulb Temperature Evaporative Cooling Using Porous Ceramic Materials. Retrieved from https://www.researchgate.net/publication/267209957_Mathematical_Modeling_of_a_Sub-Wet_Bulb_Temperature_Evaporative_Cooling_Using_Porous_Ceramic_Materials , Condair. (2021, January 5). Direct vs. Indirect Evaporative Cooling: What's the Difference? Direct vs indirect evaporative cooling whats the difference. Retrieved April 16, 2022, from https://www.condair.com/humidifiernews/blog-overview/direct-vs-indirect-evaporative-cooling-whats-the-difference , ategroup. (n.d.). Evaporative cooling system: Indirect direct evaporative cooler. A.T.E. India. Retrieved April 16, 2022, from https://www.ategroup.com/hmx/why-evaporative/

Radiant and Chilled Beam Systems: Low Energy Cooling Systems



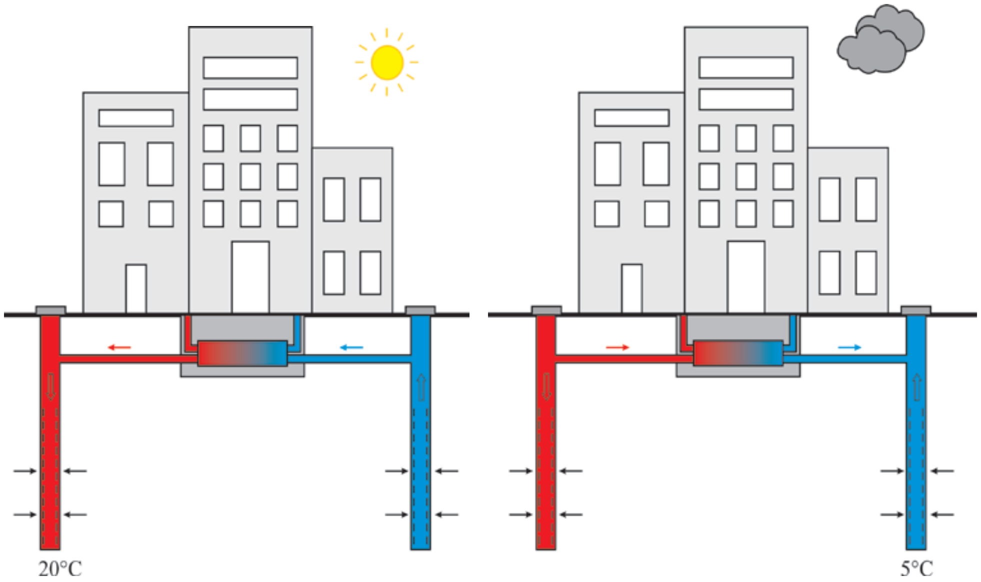


- **Favorable Factors**
  - Very efficient for sensible loads
  - Better temperature distribution
  - Use of thermal mass – structural cooling

- **Unfavorable Factors**
  - Dew point control
  - Limitations on cooling delivery
  - Secondary system for humidity removal

Source: Ehrlich, B. (2010, March 31). Active Chilled Beams: Saving Energy and Space. Retrieved from https://www.buildinggreen.com/product-review/active-chilled-beams-saving-energy-and-space
Radiant Cooling Systems. NZEB. (2020, August 21). Retrieved April 16, 2022, from https://nzebnew.pivotaldesign.biz/knowledge-centre/hvac-2/radiant-cooling-systems/

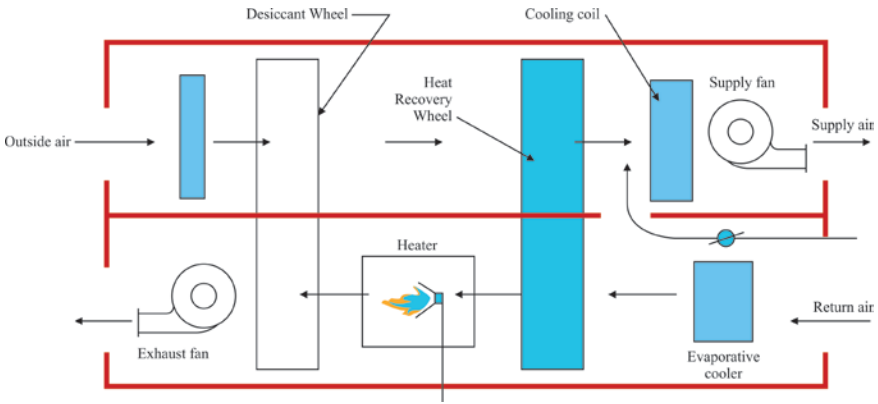
Ground and Aquifer Cooling: Low Energy Cooling Systems



- **Favorable Factors**
  - Stable earth or water temperature
  - Effective for pre-cooling
  - Very low energy use
- **Unfavorable Factors**
  - Cost involved in drilling
  - Limitations on cooling delivery
  - Secondary system for control and humidity removal

Source :Schüppler, S., Fleuchaus, P., & Blum, P. (2019). Techno-economic and Environmental Analysis of an aquifer thermal energy storage (ATES) in Germany. Geothermal Energy, 7(1). https://doi.org/10.1186/s40517-019-0127-6

Desiccant Cooling: Low Energy Cooling Systems



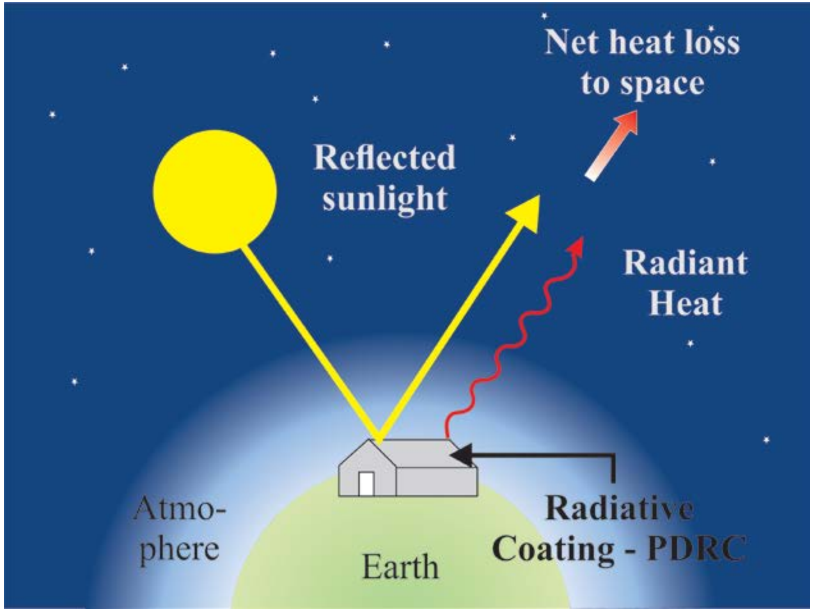
- **Favorable Factors**
  - Effective approach for moisture removal
  - New materials with better properties
- **Unfavorable Factors**
  - Regeneration - waste heat or affordable thermal source
  - Another system for controlled conditions

Source: Hybrid solar desiccant cooling system: Seminar report, PPT, PDF for Mechanical. Hybrid solar Desiccant Cooling System | Seminar Report, PPT, PDF for Mechanical. (n.d.). Retrieved April 16, 2022, from https://www.seminarsonly.com/mech%20&%20auto/Hybrid-Solar-Desiccant-Cooling-System.php

Challenges in Deploying Low Energy Cooling Systems

- **Limited Applications**
  - Suitability in specific application
  - Achieving comfort conditions under a wide variety of outdoor and indoor condition
- **Controllability**
  - Precise temperature and humidity conditions
- **Testing Protocols**
  - Ability to demonstrate the benefits vis-à-vis traditional units
  - Moisture removal rate

Emerging Low Energy Cooling Systems



- **Market Available**
  - Radiative Sky Cooling - heat exchange with deep space (8-13 µm)
  - Multiple-stage Evaporative Coolers
  - Vapor absorption and adsorption
- **Research phase - Prototype**
  - Barocaloric cooling
  - Membrane-based by dehumidification
    - Isothermal, hygroscopic nanofibrous
  - Automatic Water Generators
  - Carbon Dioxide Adsorption

Source: Yang, Y., & Zhang, Y. (2020). Passive daytime radiative cooling: Principle, application, and economic analysis. MRS Energy & Sustainability, 7(1). https://doi.org/10.1557/mre.2020.18

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Thank you

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