solar cooling
sustainable air conditioning for Barbados

Johannes Pelda ● Rasmus Borrmann

Solar Cooling
Agenda

Introduction

Thermodynamic Basics

Sorption Chilling Processes

Project Approach

solar cooling – sustainable air conditioning for Barbados

INTRODUCTION

Barbados
Geography

Location: Carribean, North Atlantic Ocean, NE of Venezuela

Area: 450 km²

Coastline: 97 km

Land use:

arable land:	37.21%
permanent crops:	2.33%
other:	60.46%

Natural resources:
petroleum, fish, natural gas

source: CIA – The Factbook, Google

Barbados
People, Society, Economy

Language: Englisch

Population: 283,733 inhabitants

Capital: Bridgetown (80,000 inhabitants)

GDP - official exchange rate: US$ 4.4 billion

GDP – composition by sector:

agriculture:	3.4%	(sugarcane, vegetables, cotton)
industry:	13.4%	(light manufacturing)
services:	83.2%	(tourism)

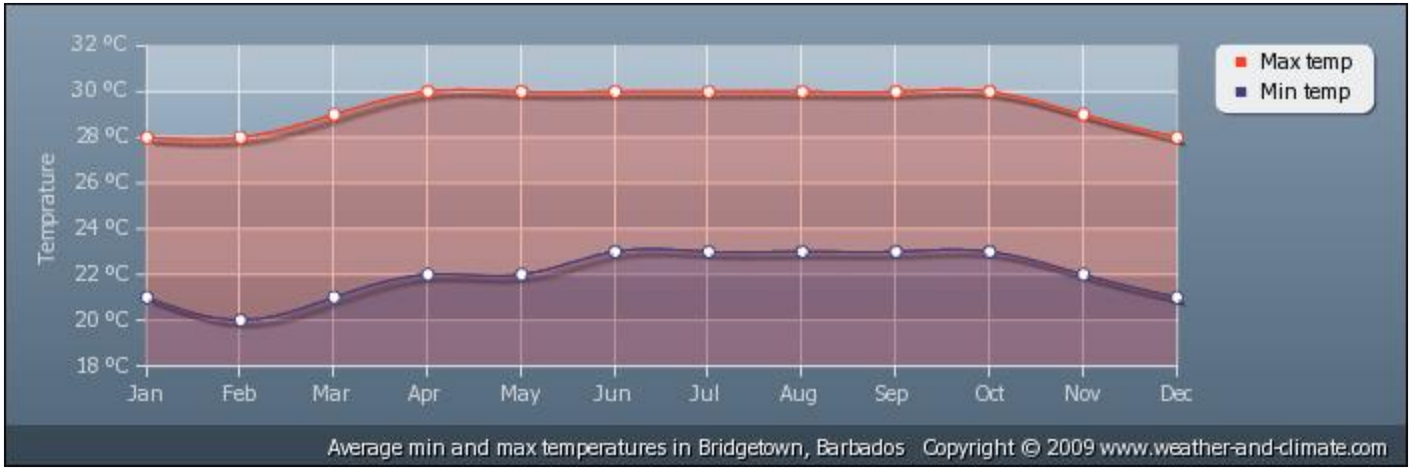
Unemployment rate: 12%

Public debt: 103.9% of GDP

Inflation rate: 7.4%

source: CIA – The World Factbook

Barbados
Climate



source: www.weather-and-climate.com

Barbados
Energy Supply

Electricity production:

heavy fuel oil: 82%

diesel: 18%

fuel is imported – high degree of volatility in the market

extensive use of solar water heaters SWH

no domestic heating – solely hot water needed

Spring Garden Generating Station: 51MW

source: www.reegle.info

Barbados
Energy Supply

THE BARBADOS LIGHT & POWER COMPANY LIMITED

DOMESTIC TARIFF CALCULATOR | GENERAL SERVICE TARIFF CALCULATOR | SVP TARIFF CALCULATOR | LP TARIFF CALCULATOR

ENERGY USAGE (kWh): 400 kWh

BILL TOTAL: $284.07

SEQUENCE	DESCRIPTION	CALCULATED AMOUNT
Customer Charge		$10.00
Energy 1st Blk	150 kWh @ 0.150 per kWh	$22.50
Energy 2nd Blk	250 kWh @ 0.176 per kWh	$44.00
Fuel Charge	400 kWh @ 41.3151 cents per kWh	$165.26

SUB TOTAL: $241.76

VAT: $42.31

CURRENT BILL: $284.07

Exchange Rates

1 BBD = 0.50 USD
1 USD = 2 BBD

1 BBD = 0.38 EUR
1 EUR = 2.60 BBD

Electricity Prices (400 kWh per month)

Barbados Light and Power
109.26 EUR
1 kWh = 0.27 EUR

Stadtwerke Flensburg
100.67 EUR
1 kWh = 0.25 EUR

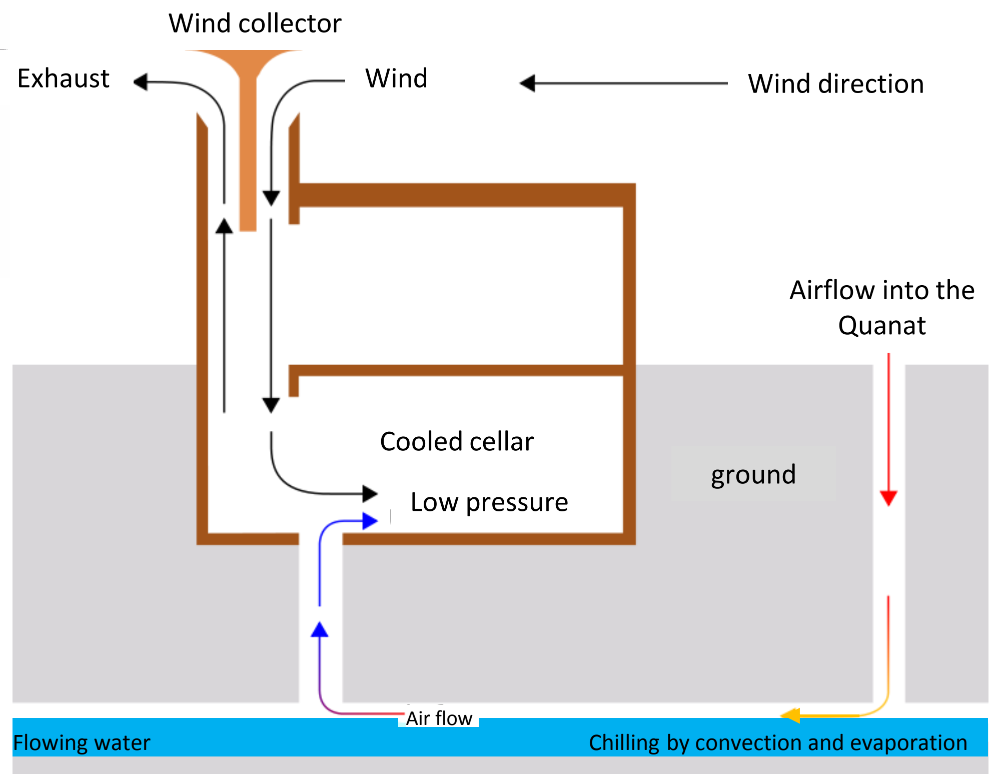
source: Barbados Light and Power Ltd.

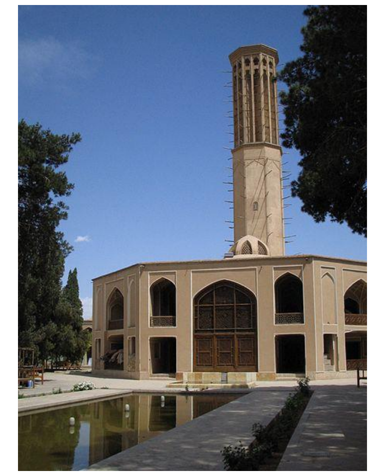
solar cooling – sustainable air conditioning for Barbados

THERMODYNAMIC BASICS

Thermodynamic Basics
Evaporative Cooling

Fidel





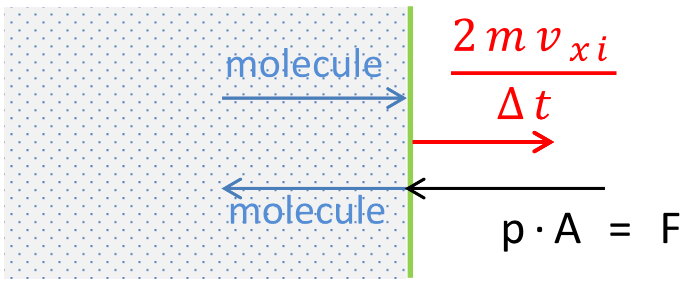
The Bādgir of Dowlat-abad in Yazd is one of the tallest airscoops

http://de.wikipedia.org/wiki/B%C4%81dgir

Thermodynamic Basics
Evaporative Cooling

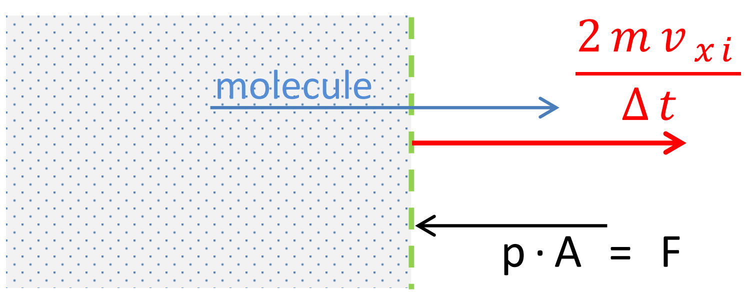
- <u>Puls transmission:</u> $\Delta G_i = 2mv_{xi}$

$\frac{\Delta G_{total}}{\Delta t} < p \cdot A$



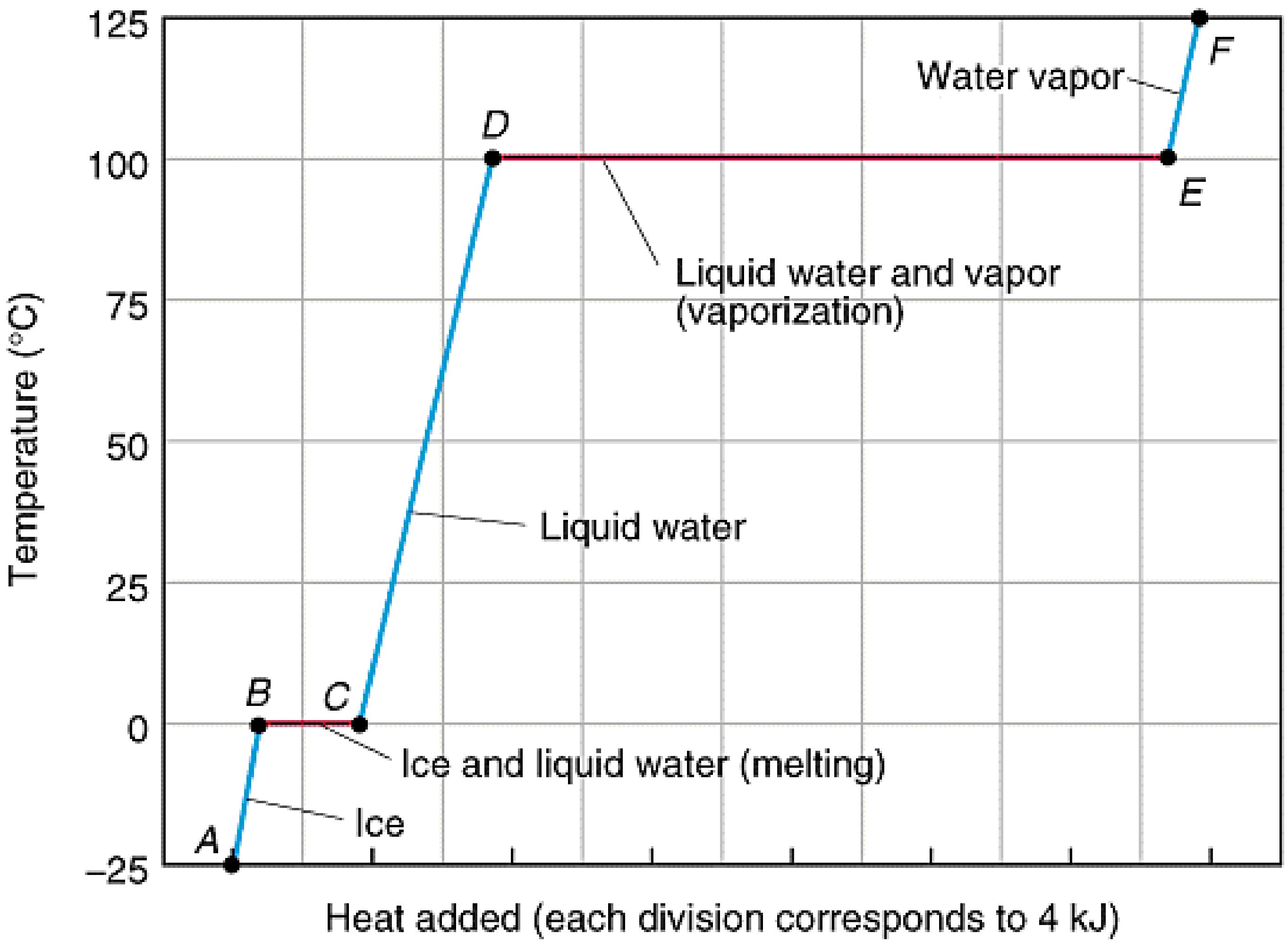
Not evaporating

$\frac{\Delta G_{total}}{\Delta t} > p \cdot A$



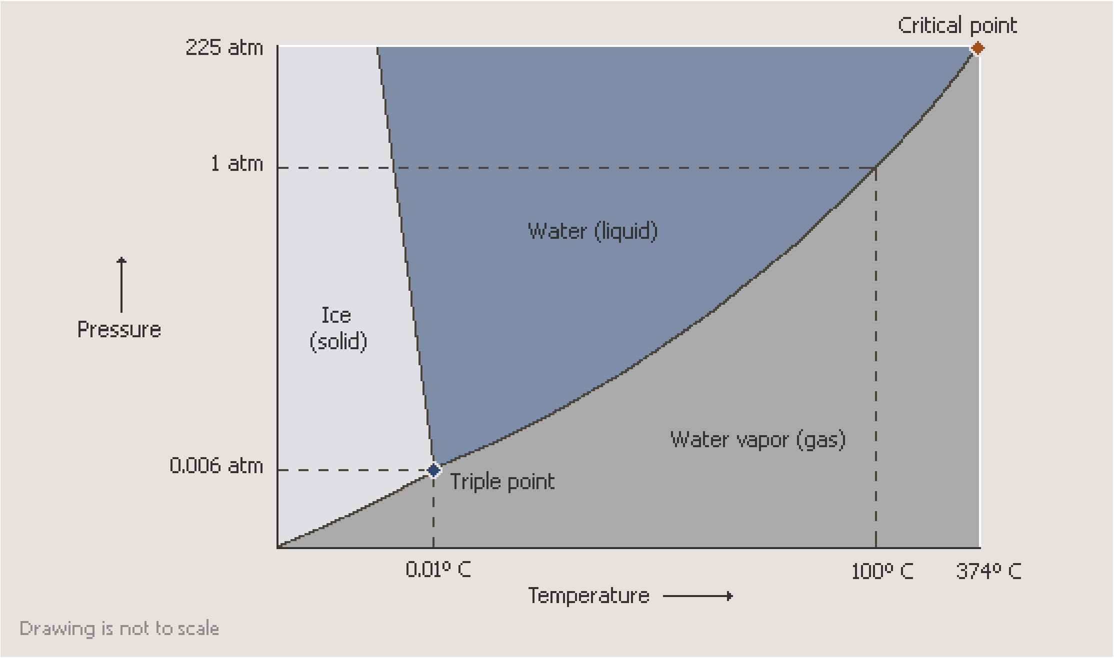
Evaporating

Thermodynamic Basics
Water Phases



Source: http://www.energie.ch/gasgleichungen

Thermodynamic Basics
Water Phases

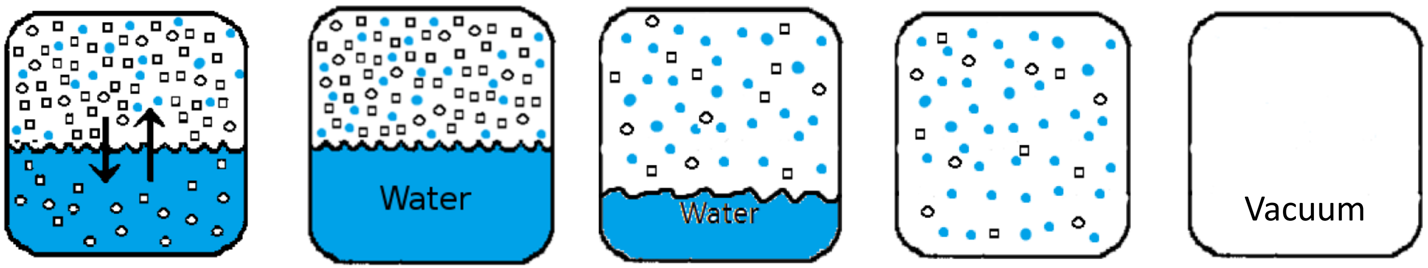


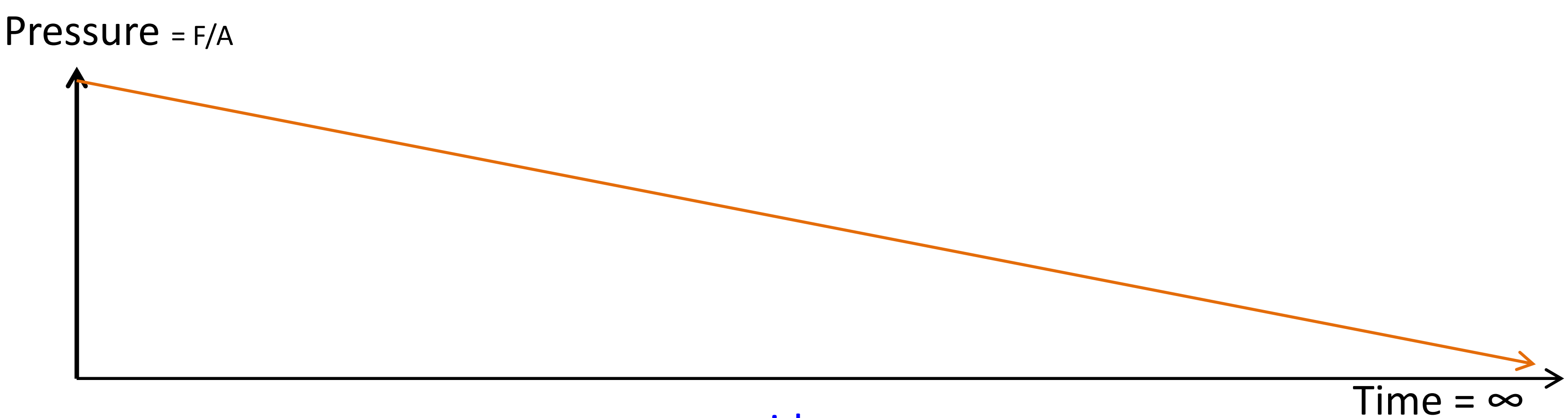
http://www.askamathematician.com

Thermodynamic Basics
Water Phases

The total pressureof a systemisgivenby

$$p_{total} = p_{water} + p_{gas}$$



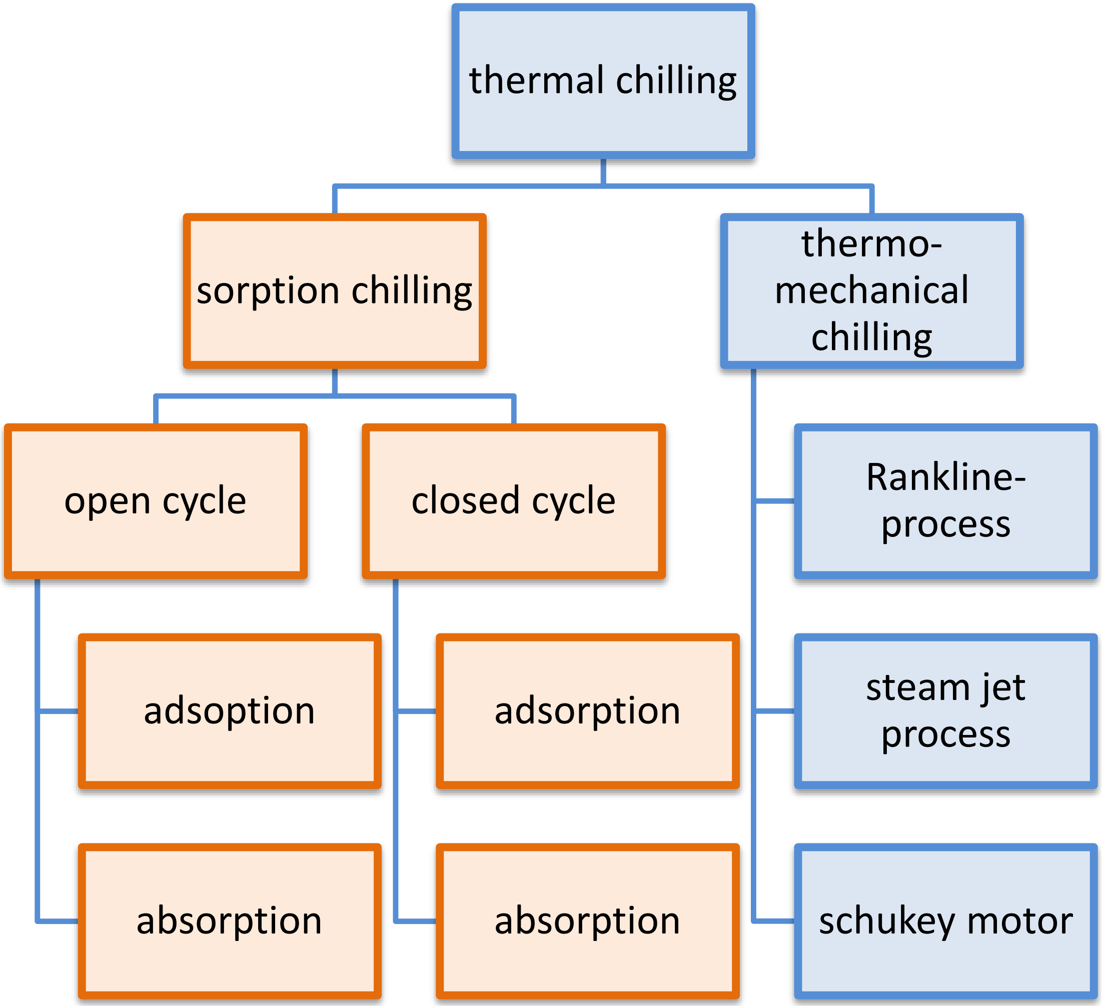


video

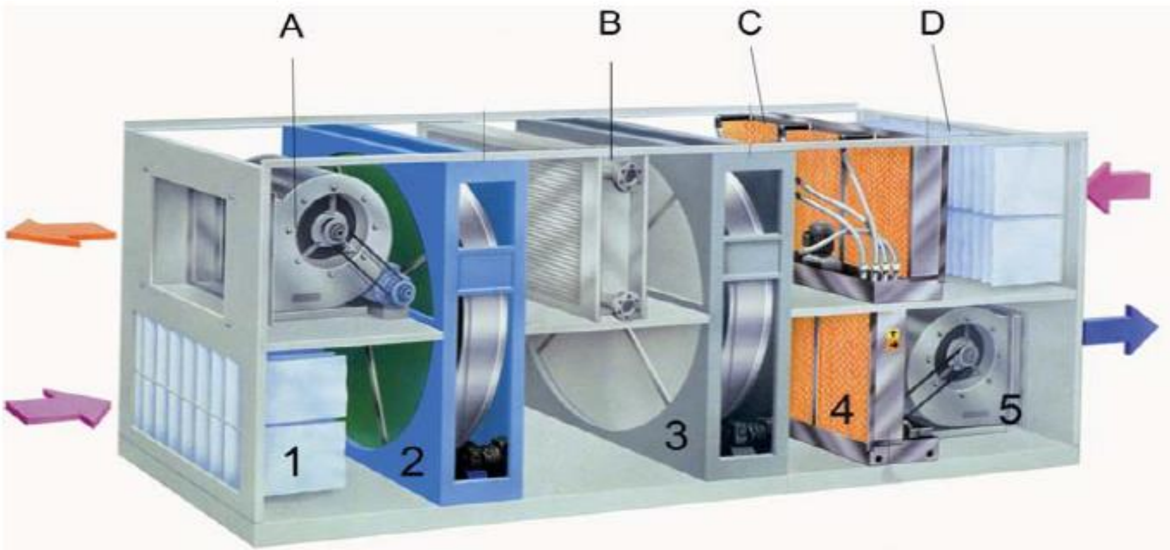
solar cooling – sustainable air conditioning for Barbados

SORPTION CHILLING PROCESSES

sorption chilling processes
system overview

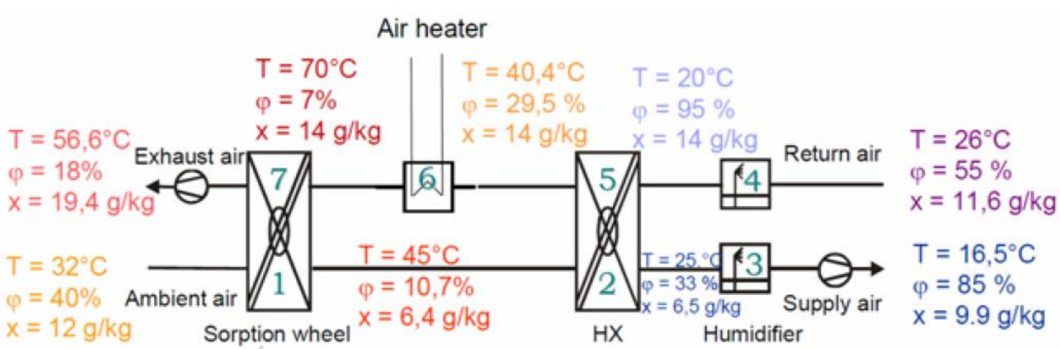


open sorption chilling processes
adsorption



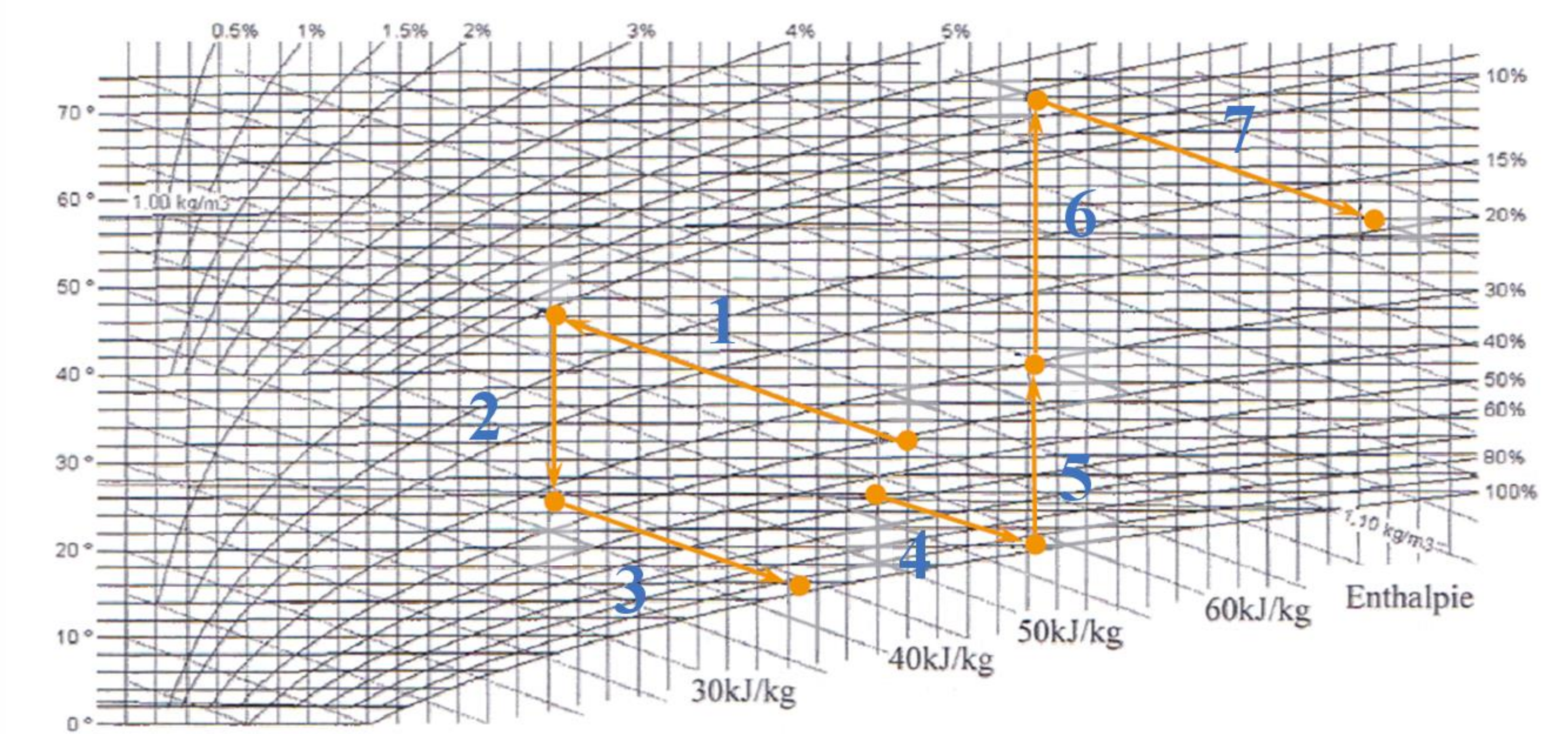
Discharge air side
- A. Discharge air fan
- B. Regeneration heater
- C. Evaporative cooler
- D. Filter

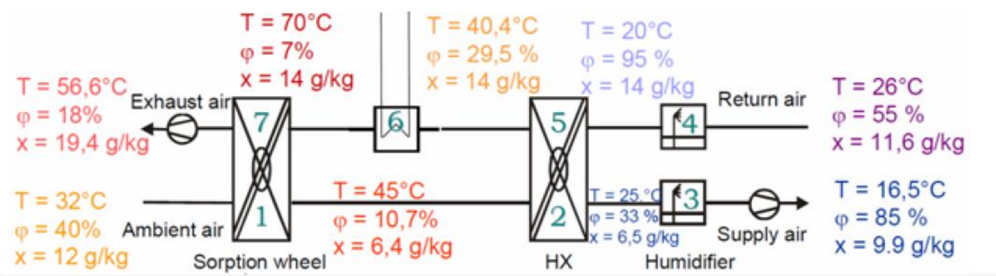
Supply air side
1. Filter
2. Sorption rotor
3. Heat recovery rotor
4. Evaporative cooler
5. Supply air fan



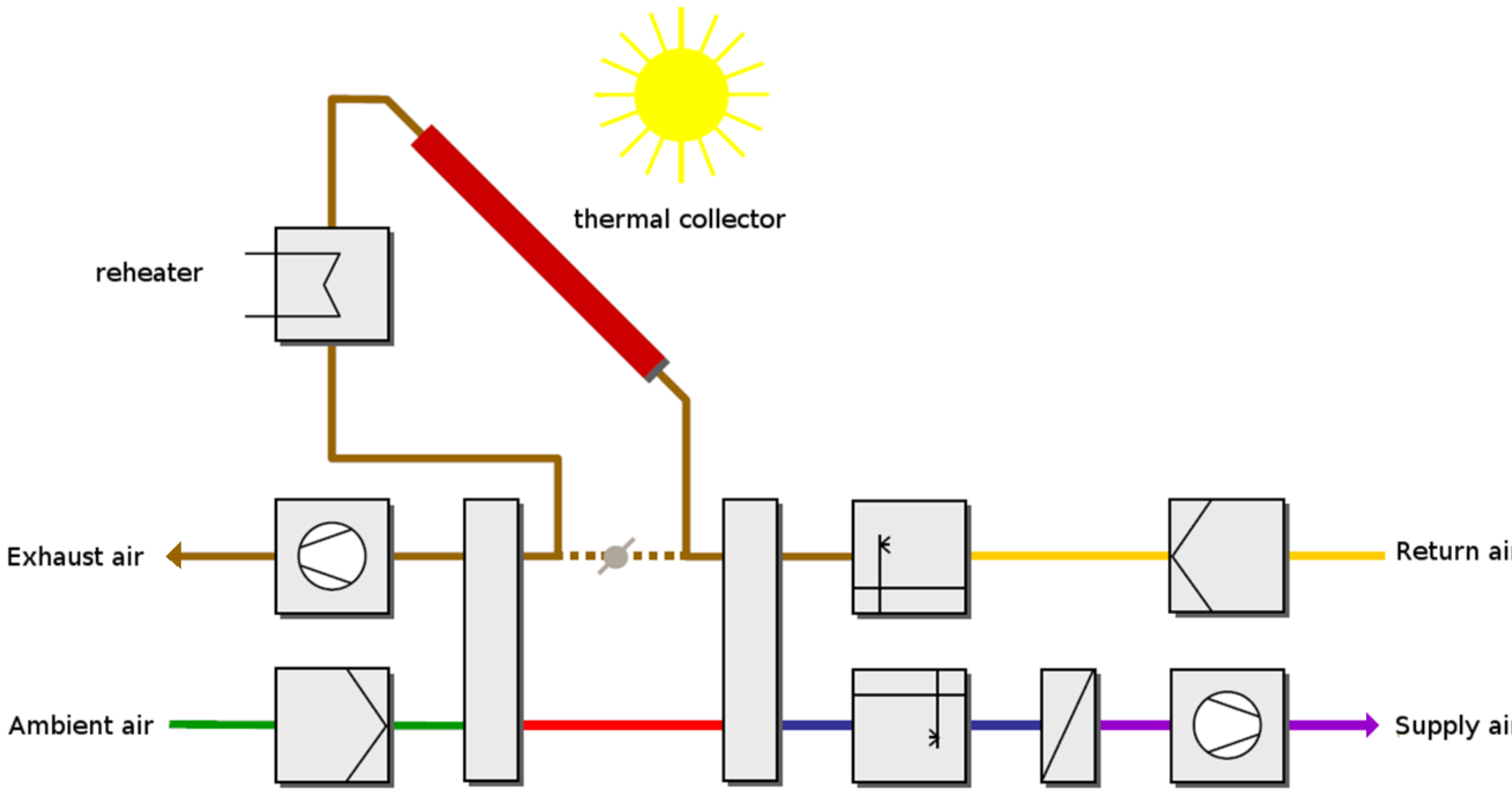
source: Munters Austria, www.munters.com.au

open sorption chilling processes
adsorption



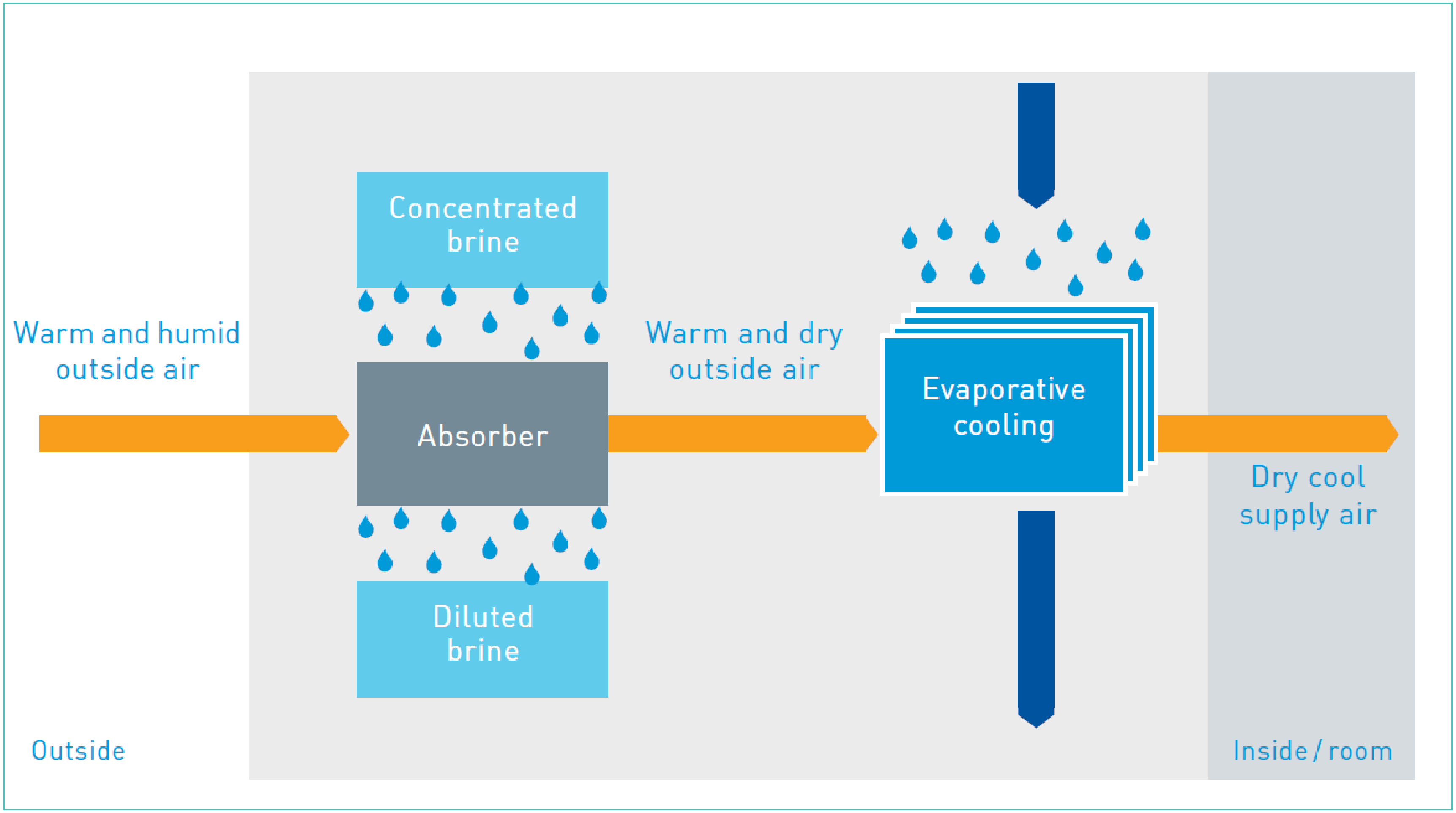


open sorption chilling processes
adsorption



source: Müsch (adapted)

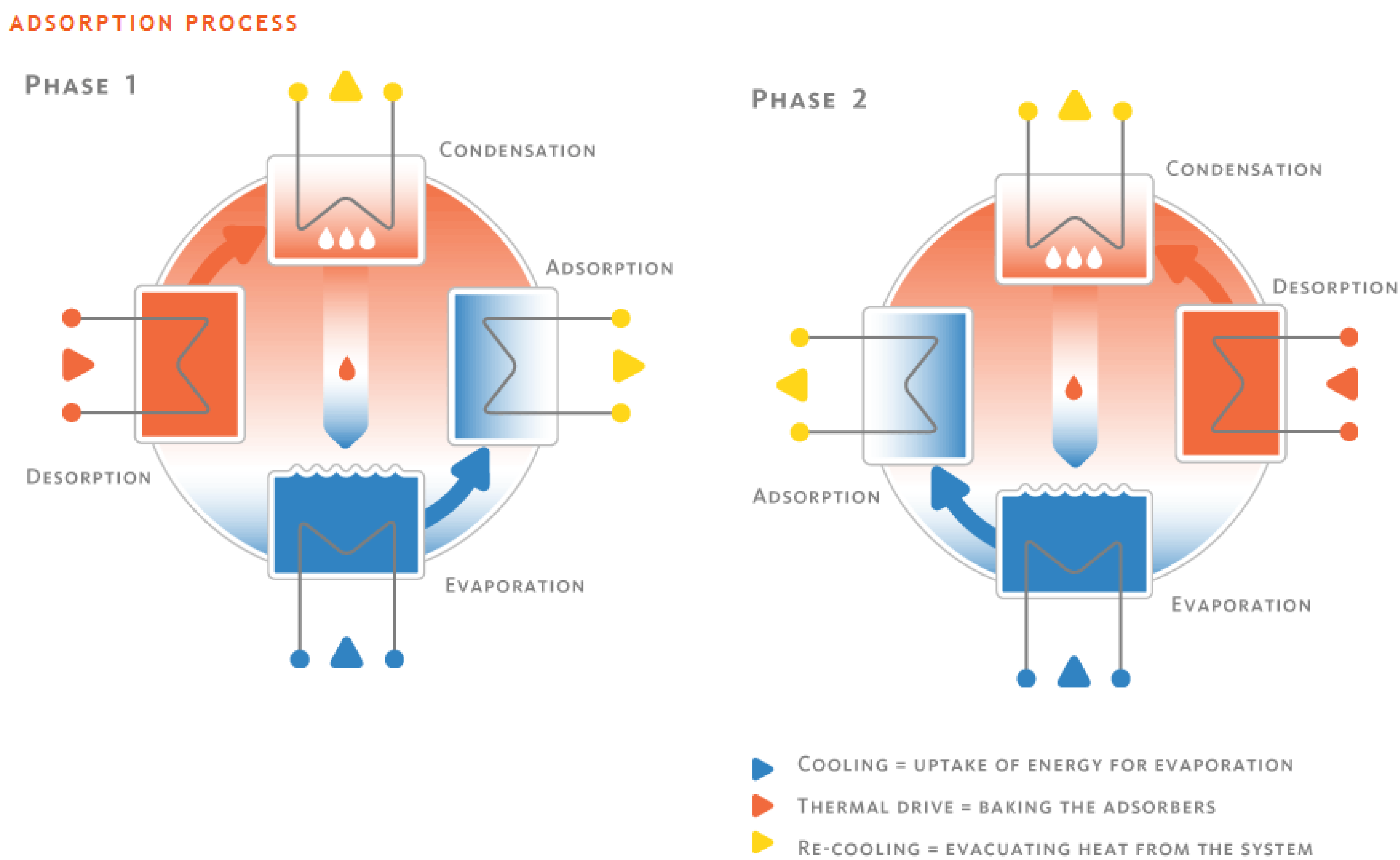
open sorption chilling processes
absorption



source: Menerga

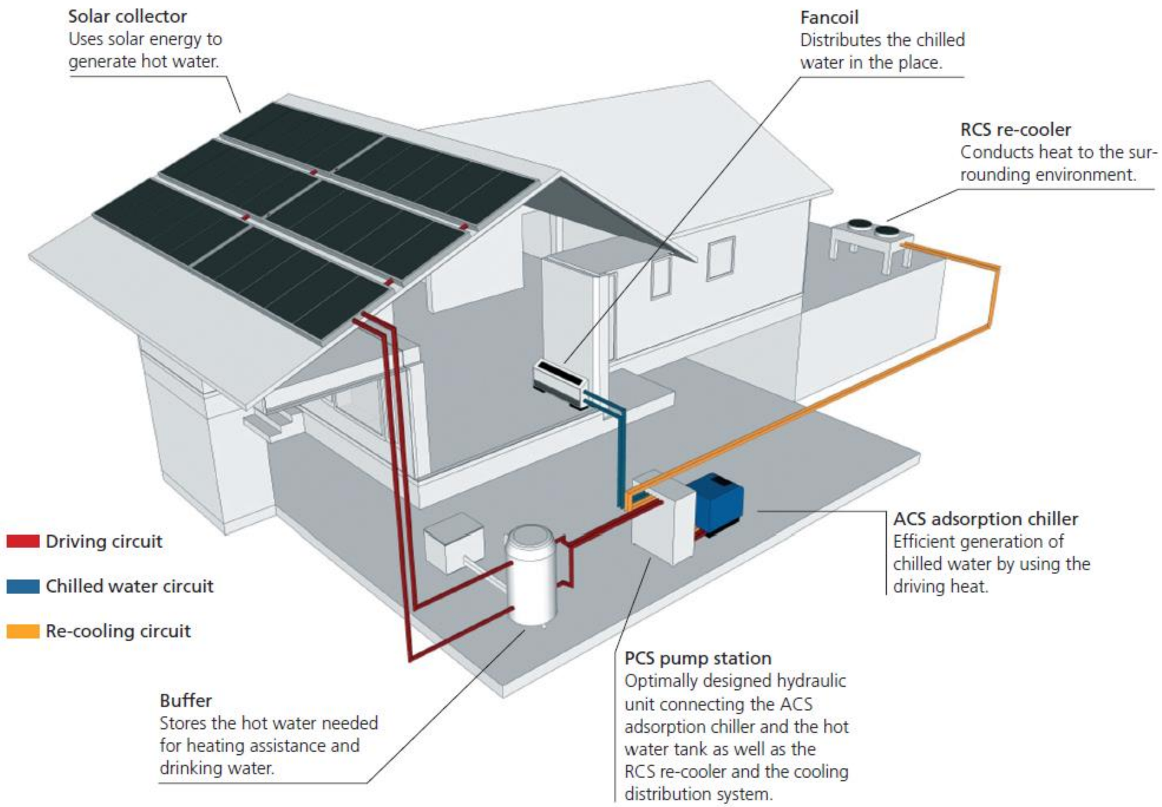
closed sorption chilling processes

adsorption



source: Invensor

closed sorption chilling processes
adsorption



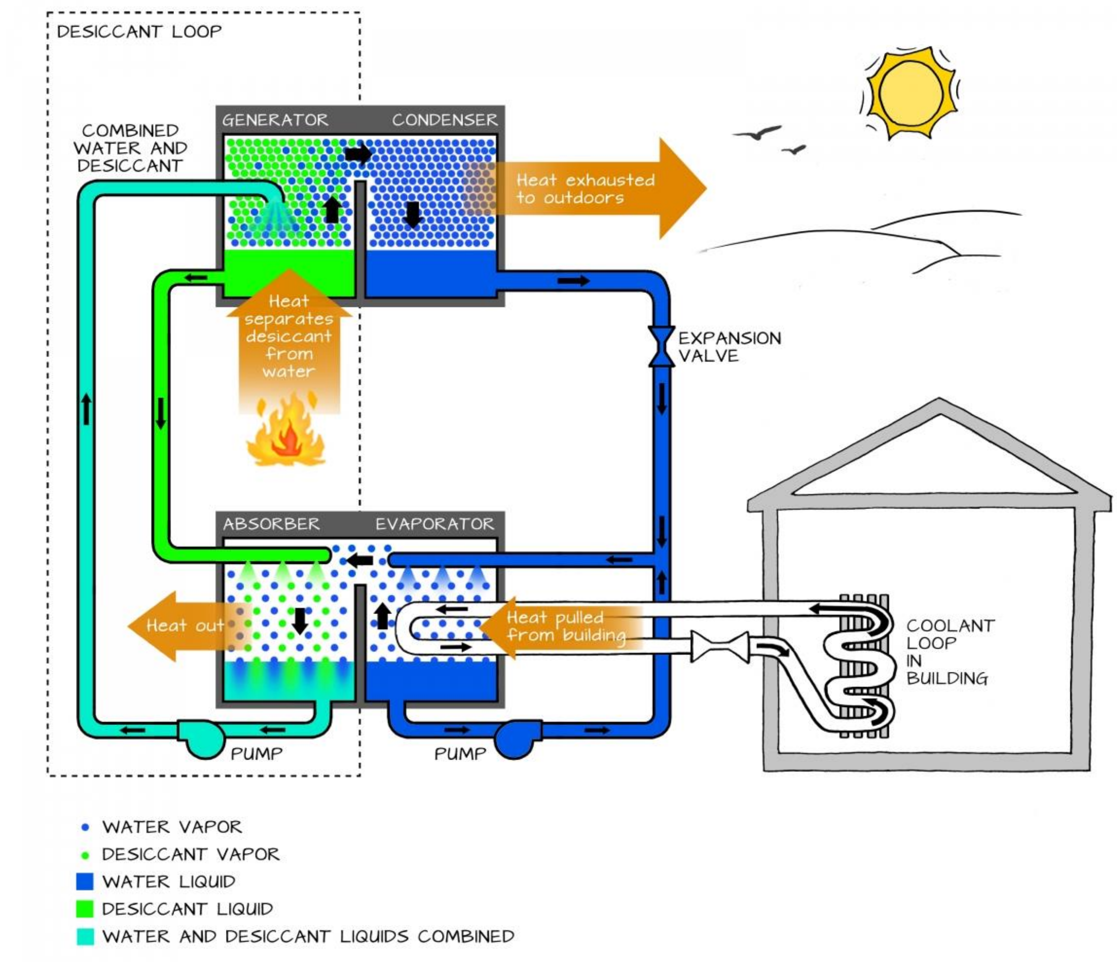
source: SorTech AG

closed sorption chilling processes
adsorption

source: SorTech AG

closed sorption chilling processes

absorption



source: Autodesk Education Community

sorption chilling processes
annual electricity costs

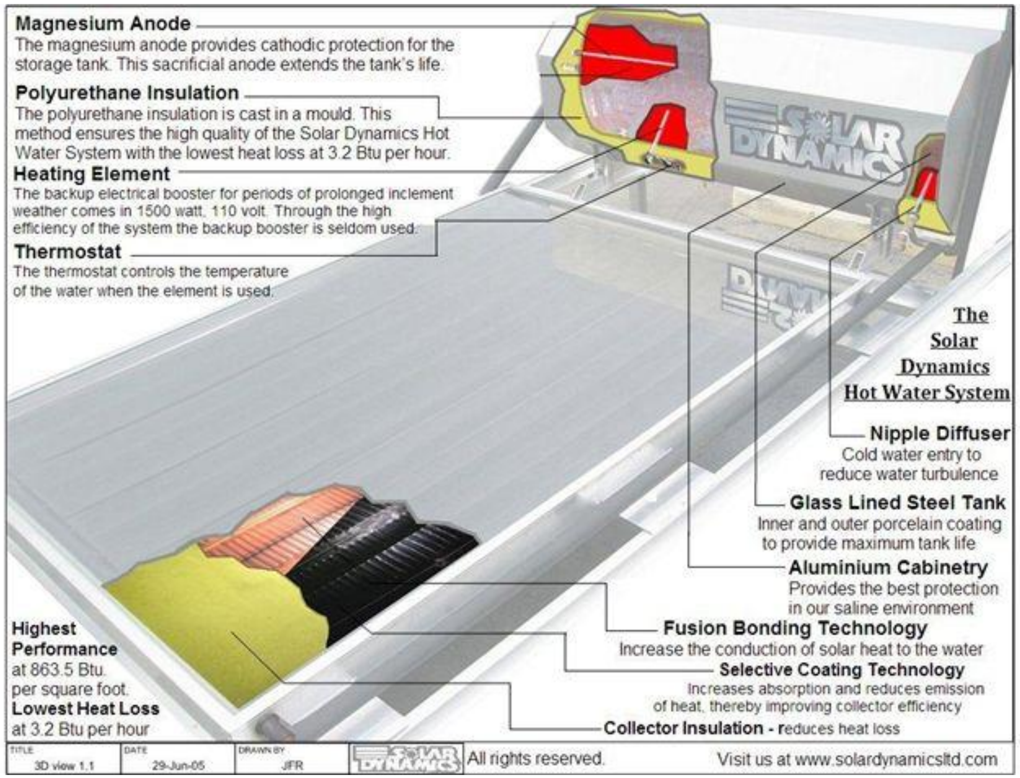
	conventional chilling	solar chilling
Office building size in m²	250	
Refrigeration load in Wh/m²d	200	
Refrigeration load of the office in kWh/a	18 250	
Seasonal performance factor	5 - 6	10 - 13
Electricity needed in kWh/a	3650	1825
Electricity cost in Euros	1 254	561

solar cooling – sustainable air conditioning for Barbados

PROJECT APPROACH

Project Approach

Contacts



[video]

source: Solar Dynamics Ltd.

Project Approach

Contacts

HIPAC
LIMITED

Source: Hipac Ltc.

Project Approach
Contacts

THE UNIVERSITY OF THE WEST INDIES
AT CAVE HILL, BARBADOS

Tom Rogers, PHD
Professor
Renewable Energy Management

Prof Sir Hilary Beckles
Principal UWI

Government
of Barbados

Ruall Harris
Former Permanent Secretary in the Ministry

Project Approach
SWOT Analysis

strengths
- know-how
- contacts

weaknesses
- distance

opportunities
- climate conditions
- power price

threats
- scale of technology
- price
- missing experts

Project Approach
Outlook

Status Quo

- James Husband (solar heater supplier)
- Tom Rogers (ambitious to support the project)
- Tony Gill (Hipac, company which is interested)

Next steps

- Design of a suitable cooling system (missing information from Hipac)
- More detailed ecomical calculation (details of the system configuration required)

Next semester

- Travel to Barbados
- Support of INEES funds
- Master Thesis UWI

Thanks for your attention!

Thermodynamic Basics
Equations

- Force: $F = \frac{\Delta G_{total}}{\Delta t} = p \cdot A$

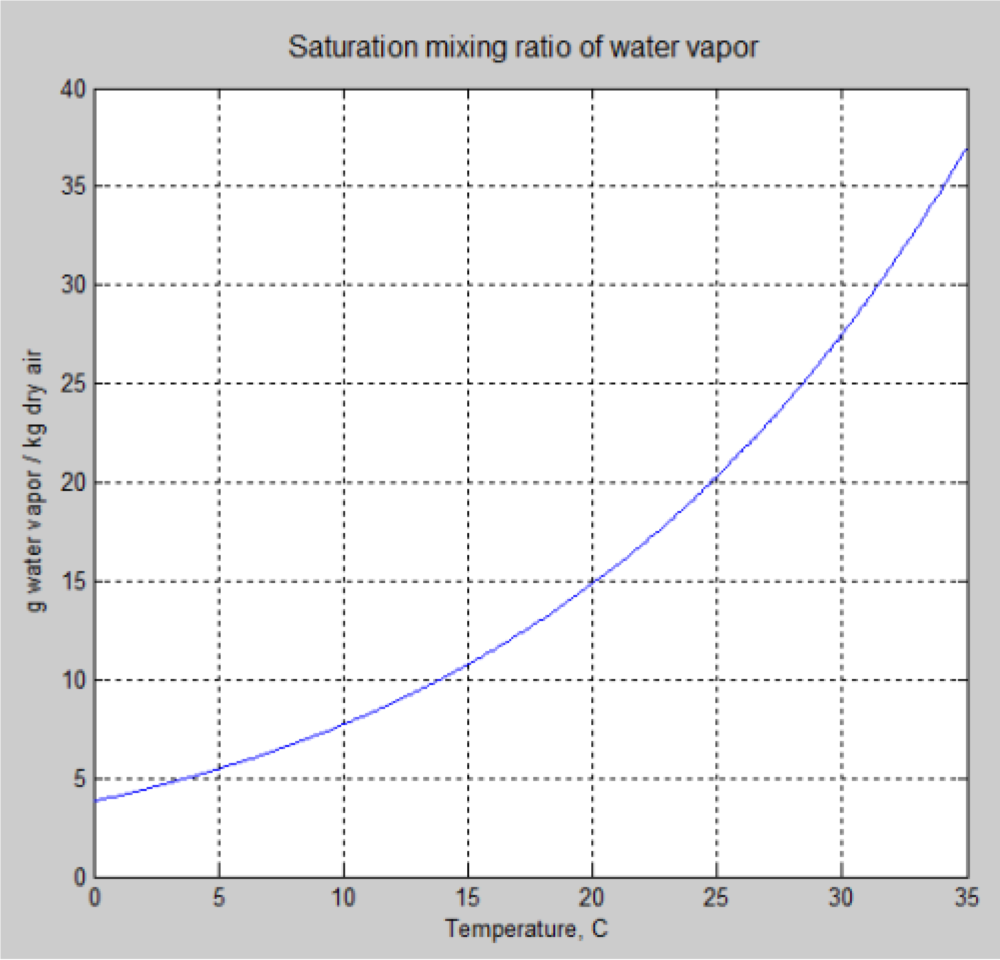
- Equation of state: $p = \frac{m \cdot R_s}{V} \cdot T$

- Water vapour pressure: $p_{wvp} = \varphi \cdot p_{sd} = p$

(p_{sd} = 31,7mbar (25°), φ = relative air moisture)

Source: Physikalische Formeln und Tabellen, j. Lindauer Verlag

Thermodynamic Basics
Saturation of Water Vapor



Google pictures

closed sorption chilling processes
pros and cons

open		closed	
adsorption	absorption	adsorption	absorption
+ air conditioning possible + low driving heat temperature + every heat useable + low driving heat temperature + non-hazardous coolant - size and weight - contamination of sorbent - no storage of coldness	+ air conditioning possible + low driving heat temperature + every heat useable + storage of coldness - size and weight - odor and material transmission	+ cold water + independent from ambient air humiditiy - expensive - lower COP	+ low temperature coldness possible + part load performance - expensive - danger of cristallisation - ammoniac hazardous

solar cooling – sustainable air conditioning for Barbados

CONVENTIONAL CHILLING

conventional chilling