CSP cooling systems: water and energy demands

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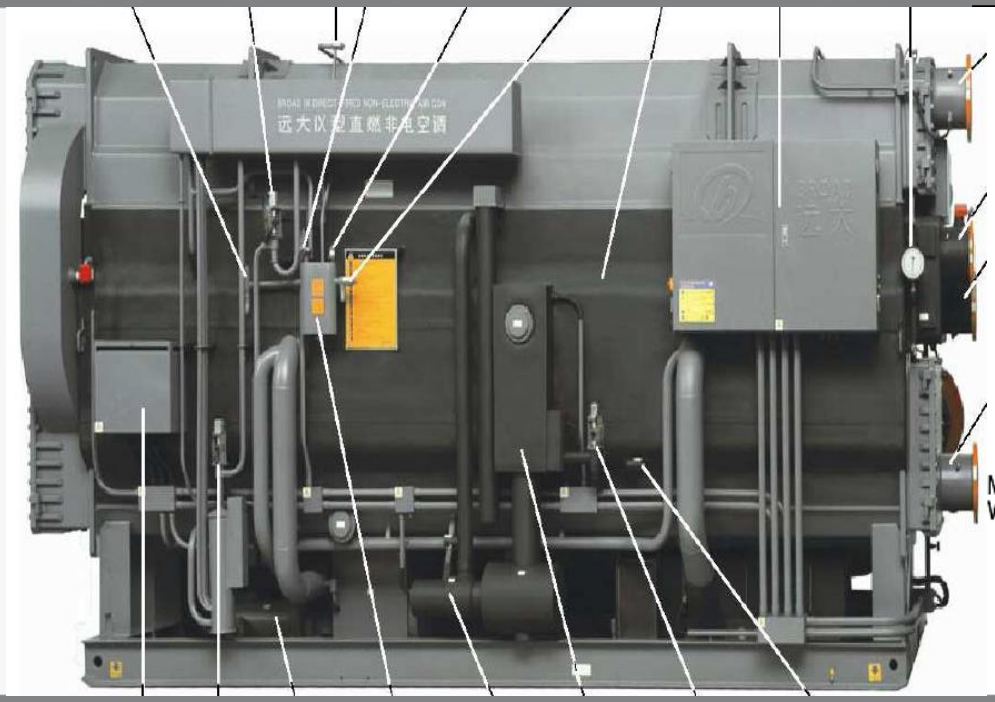

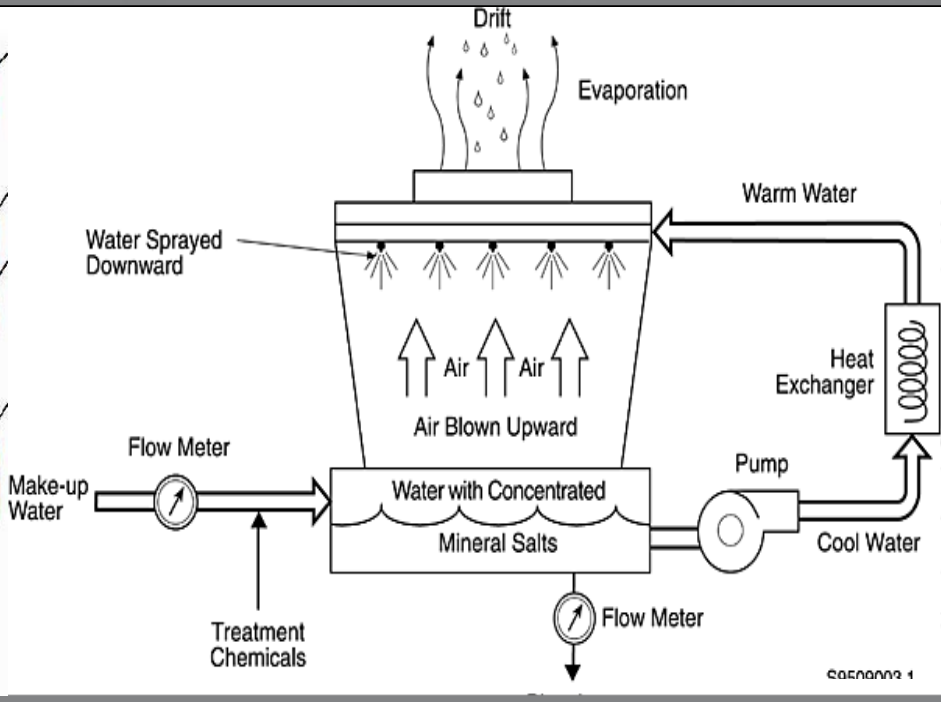

Dr. Kumar Patchigolla

1st December 2015

Outline of presentation

- Why the renewed interest?
  - Advantage and disadvantages
- Spotlight on energy in UK/EU
- Recent projects
  - EU FP7—MATS
  - Horizon 2020—WASCOP
- Spotlight on RHI

Why the renewed interest in CSP?

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COP21: A very high-level, but absolutely crucial, discusses 'six thematic areas with high mitigation potential, opportunities for action and various co-benefits, namely

- renewable energy,
- energy efficiency,
- the urban environment (including transport),
- carbon capture, use and storage,
- methane and other non-CO_2 GHGs and
- land use.

COP21: Paris conference could be climate turning point, says Obama

30 November 2015 | Science & Environment | 1037

Dept of Energy & Climate Change - HM Government Statement Re Carbon Capture, Storage
Released 14:57 25-Nov-2015

RNS Number : 9664G
Dept of Energy & Climate Change
25 November 2015

£1 billion ring-fenced capital budget for the CCS Competition is no longer available

HM Government Statement to Markets Regarding Carbon Capture and Storage Competition

25 November 2015

Today, following the Chancellor's Autumn Statement, HM Government confirms that the £1 billion ring-fenced capital budget for the Carbon Capture and Storage (CCS) Competition is no longer available.

This decision means that the CCS Competition cannot proceed on its current basis. We will engage closely with the bidders on the implications of this decision for them.

Why the renewed interest in CSP?

Fossil plants	CSP plants
Combustion of fossil fuel or heat from nuclear reactors	Substitutes concentrated high temperature solar heat Close resemblance to fossil plants Increasing utility interests to meet the 2050 targets
Use the collected heat to power-conventional Rankine steam cycles Use many of same technologies and equipment for water and energy demands	

- *Equal attention given to renewables and CCS in the UNFCC document.*
- *Legally binding EU 2020 targets of 15% of total energy from renewables*

Advantages

- Resemble traditional power plants
  - generation based on steam and is large scale
  - use standard equipment for power generation
- Can be built in small sizes and added to as needed
- Can achieve high steam operating temperatures, allowing more efficient power generation
- Capable of combined heat and power generation
  - steam for absorption chillers, industrial process heat, desalination
- Non-carbon emitting power generation
- Storage allows generation to match utility load profile

Disadvantages

- High upfront capital costs for concentrators and storage
- Require large surface areas for placement of concentrators

- Require direct normal solar radiation, thus limiting where CSP plants can be located
  - desert areas are best (but also arid)—**requires cold heat**

- Require **cooling**, as with any steam power plant, creating a requirement for **water** or air cooling
  - water limitations may necessitate air cooling in many locations,
  - with penalty in capital cost, generating efficiency and **energy** cost

Can we do better?

For a world with 10 billion people by 2050

- Is there a way to provide enough energy needs?
  - Basic needs/parameters
- Several ways:
  - Improving the efficiency
  - Reducing the water usage
  - Reducing energy costs
  - Minimising the energy losses
  - Efficient ways of utilising the heat requirements

Demand	Per person and year
Energy	5 MWh
Water	350 m^3

Spotlight on energy in UK/EU

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Morocco's pledge to get 42% of its electricity generation from renewables by 2020
UK coal plants must close by 2025

Moroccan solar plant to bring energy to a million people

By Roger Harrabin
BBC environment analyst

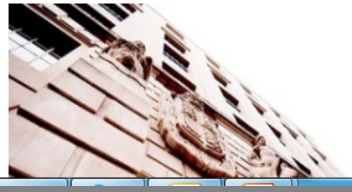
23 November 2015 | Science & Environment

Press release

New direction for UK energy policy

From: Department of Energy & Climate Change
First published: 18 November 2015

Energy and Climate Change Secretary Amber Rudd has set out her vision for an energy system that puts consumers first, delivers more competition, reduces the burden on bill-payers and ensures enough electricity generation to power the nation.



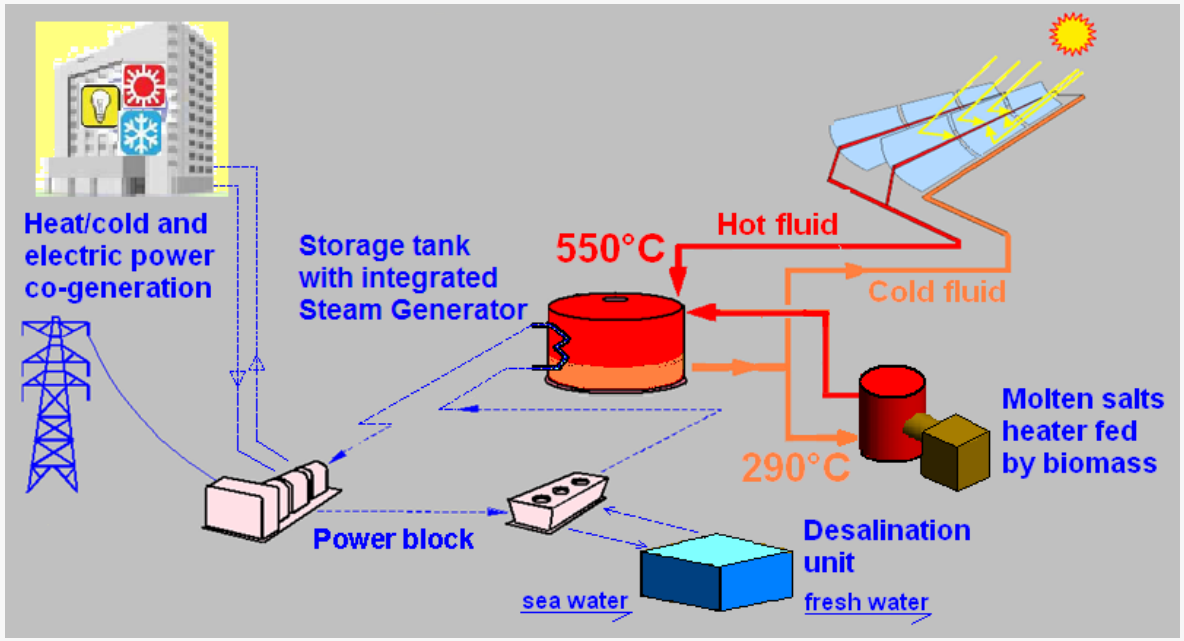
- Consultation on ending unabated coal-fired power stations by 2025
- New gas-fired power stations a priority
- Commitment to offshore wind support completes commitment to secure, low-carbon, affordable electricity supplies
- Move towards a smarter energy system

Recent projects-CSP

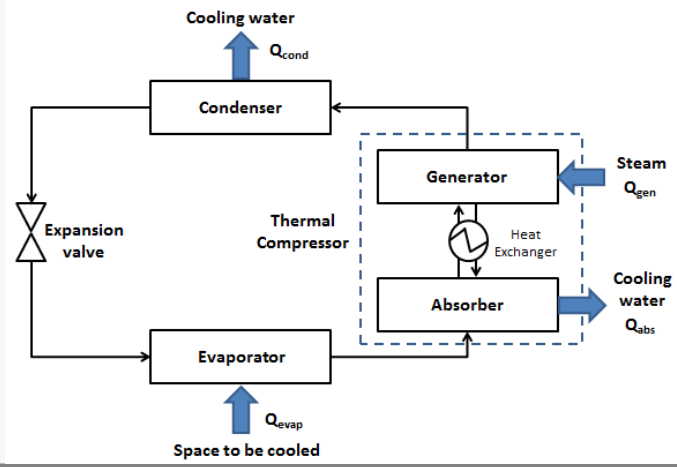
- ✓ Multipurpose applications by thermodynamic solar (MATS)–EU FP7

- ✓ Water saving for concentrated solar power (WASCOP)—Horizon 2020

MATS: 2011-2016

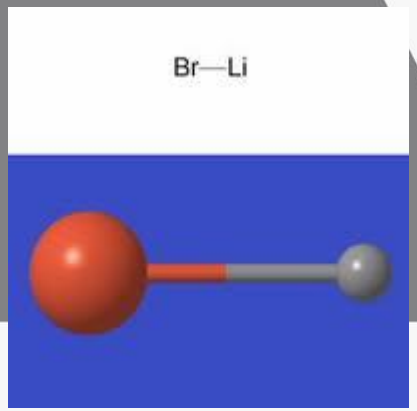


- Thermal power of $1MW_t$
- Cold generation of 300kW



- H&C cogeneration using process steam discharged from the steam turbine
- Li-Br chiller
- Generation of heating and cooling for civil and industrial uses
  - district summer cooling

Heat/cold cogeneration



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MATS

Background

- Worldwide the cooling and air conditioning market is growing
- Vapour compression units need a high amount of electric energy
- The high consumption of electricity leads to peak loads, malfunction of the power grid etc.

Thermally-driven cooling systems could be an answer

absorption chillers

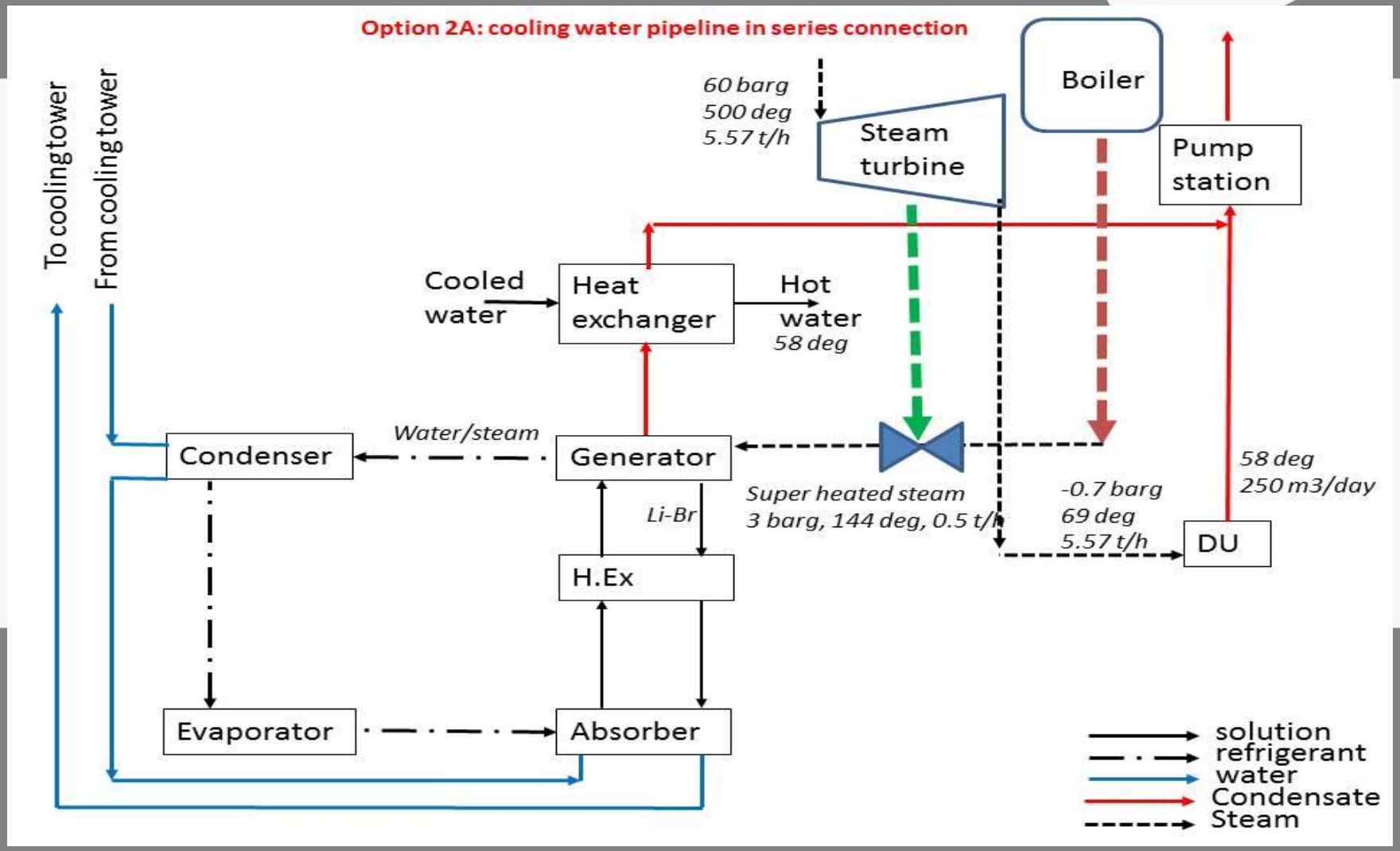
Cold is generated through the process of sorption by liquid solution

LiBr/water and NH_3/water

- Mature technology
- Several products on the market

The lithium bromide absorption system is strictly limited to evaporation temperatures above 0ºC; and the ammonia absorption system is mainly used for low temperatures below 0ºC

MATS chiller process flow diagram



Daily average weather data (Borg-Al-Arab)

Tools used in MATS programme

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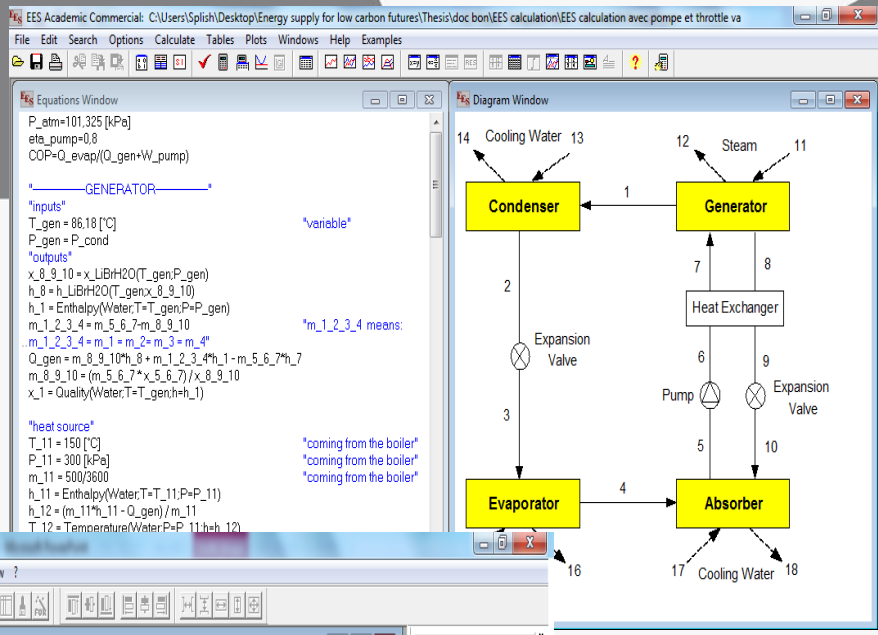
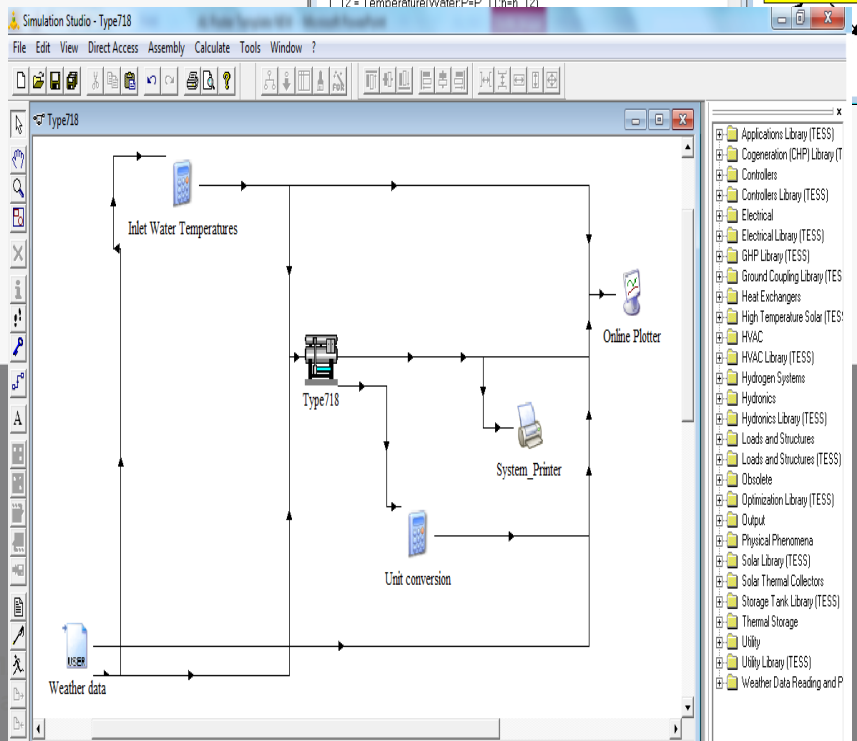




<u>Engineering Equation Solver software:</u>

- ✓ Solves a set of equations
- ✓ Provides built-in thermo-physical property and mathematical functions
- ✓ Generates graphics
- → Useful to solve problems in heat transfer, thermodynamics and optimise a system.

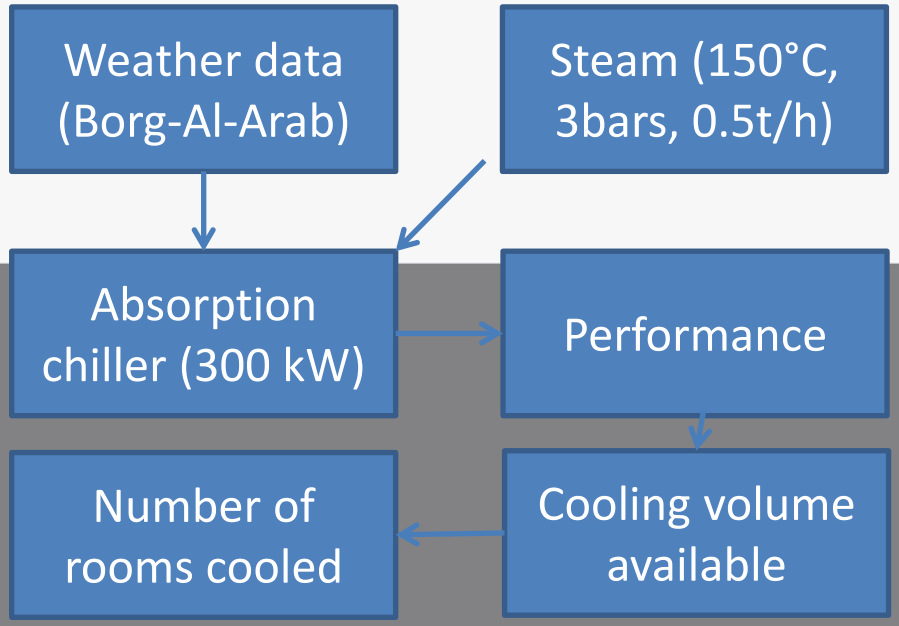
<u>TRNSYS software:</u>

- ✓ Graphically based software
- ✓ Built-in components library
- ✓ Components operate as a black box, no equations required
- → Useful to study transient systems

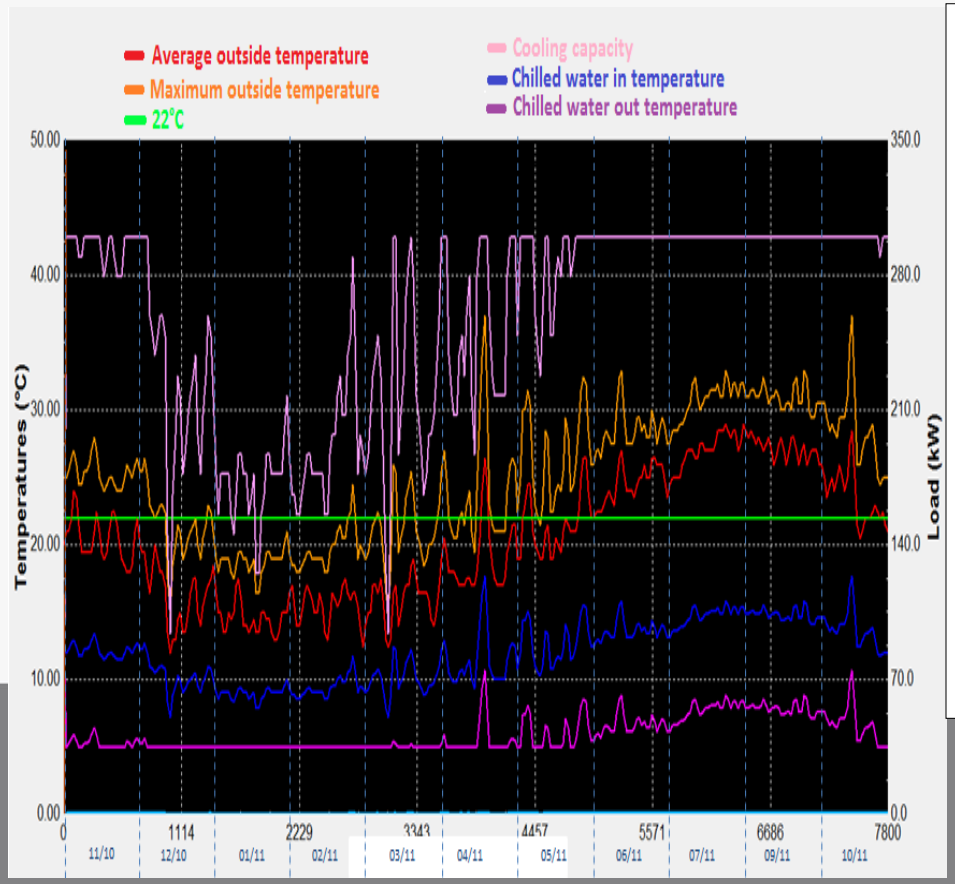
MATS dynamic simulation methodology

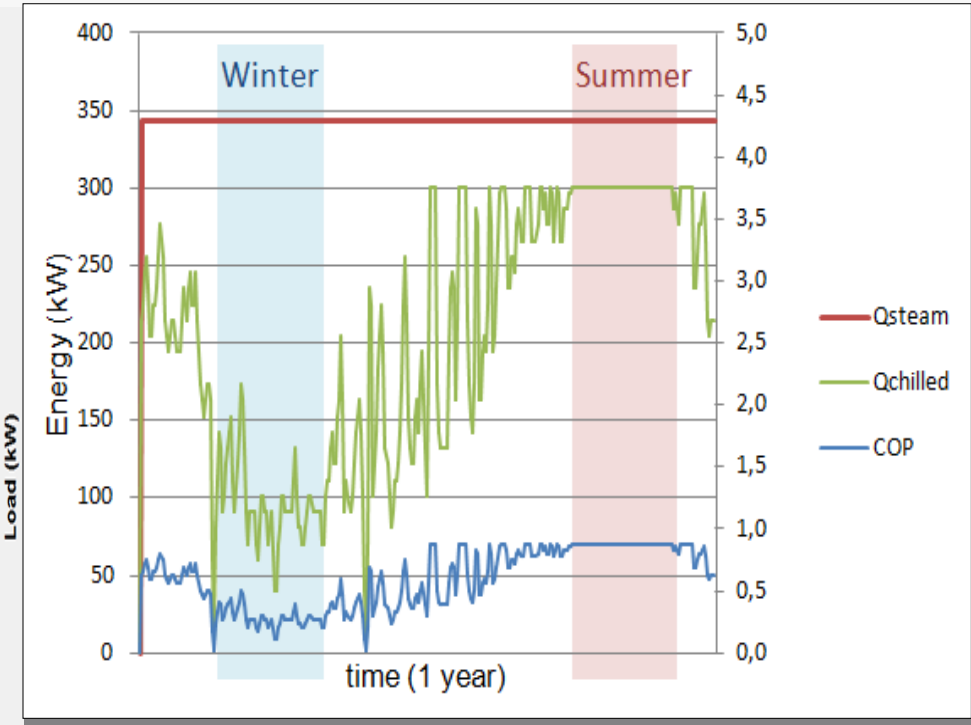
- ✓ Model the absorption chiller
- ✓ Study the impact of parameters
- ✓ Optimisation to get 300kW of cooling capacity with the best Coefficient of Performance

- ✓ Feed data from the EES model to the built-in single effect steam fired absorption chiller (TRNSYS)
- ✓ Study its performance throughout the year according to weather conditions



MATS key results

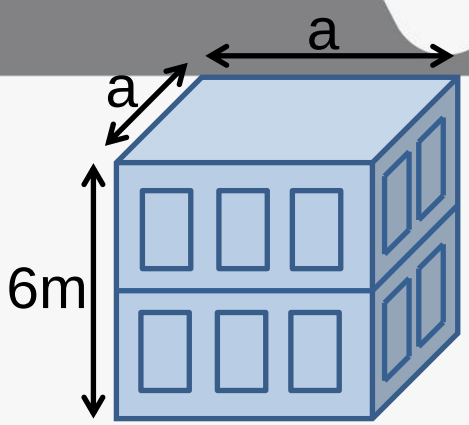




- The maximum outside temperature (orange line) is under the wanted building temperature (green line) 3 months per year
- The designed capacity is reached only half of the year

MATS cooling volume

Building Schematic



Temperature difference impact on cooling volume available

	ΔT - 10%	ΔT - 5%	ΔT [a]	ΔT + 5%	ΔT + 10%
ΔT [a] (°C)	10.8	11.4	12	12.6	13.2
a (m)	97.24	94.34	91.66	89.18	86.87
Volume cooled (m^3)	56,733	53,396	50,407	47,715	45,280
Rooms cooled [b]	630	593	560	530	503
Δ rooms	12.5%	5.9%	0%	-5.4%	-10.2%

[a] $\Delta T = T_{outside} - T_{building} = 34 - 22 = 12°C$

[b] assumption: one room = $90m^3$ = $30m^2$ x 3m

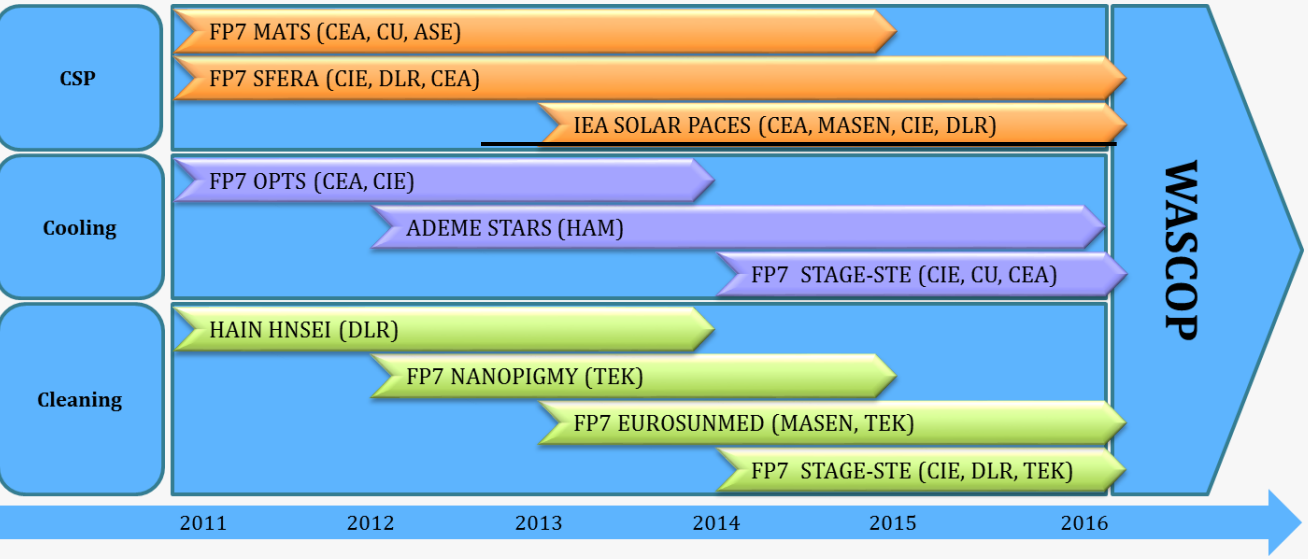
MATS key findings

- ✓ 300kW can be reached with steam leaving at 68°C (targeted value)
- ✓ Double effect chiller reduces lower input steam requirements due to its higher COP
- ✓ The designed capacity is reached only half of the year
- ✓ Cooling volume changes with the set building temperature
    - ➢ Is there legal cooling requirements?
- ✓ The chiller is not needed 3 months per year
    - ➢ Store the chilled water
    - ➢ Instead of using the heat to run the chiller, it can be used to heat up the building or for industrial needs

WASCOP: Project details

- Collaborative Project under the Horizon 2020: Developing the next generation technologies of renewable electricity and heating/cooling
- Title: Water saving for solar concentrated power
- Acronym: WASCOP
- Partners: 11 in total (7 industries)
- Website: TBA
- Duration: 4 years (20016-2020)
- Budget: 5.9 M Euro

WASCOP: vision

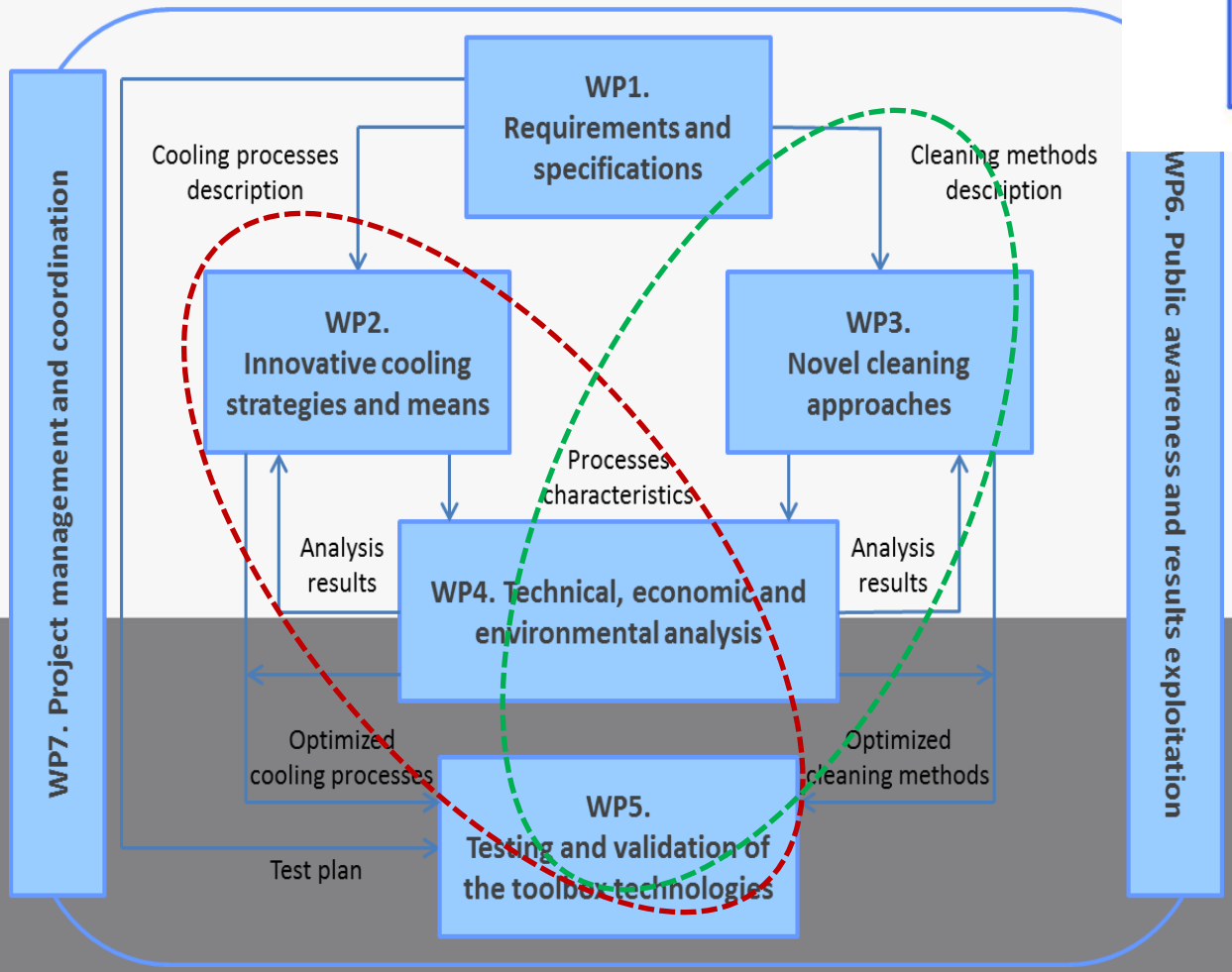


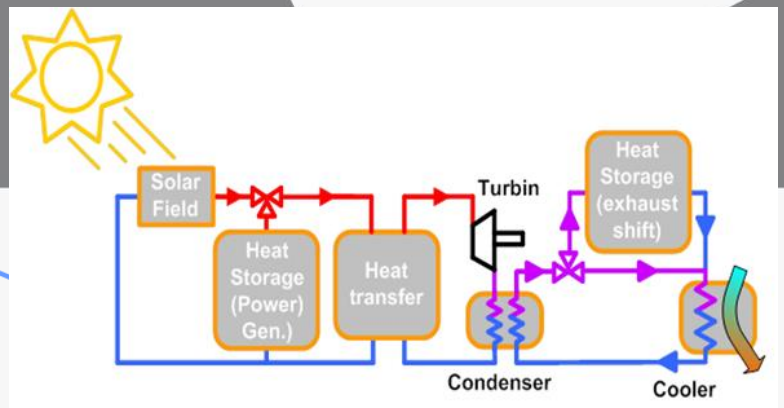
…….significant reduction in water consumption (up to 70% - 90%) and a significant improvement in the water management of CSP plants

……flexible and adaptive integrated solution encompassing different innovative technologies and optimized strategies for both the cooling of the power-block and the cleaning of the solar field optical surfaces.

Technology	Starting TRL	Expected final TRL
Hybridized cooler	TRL 3	TRL 5
Versatile cooler	TRL 3	TRL 5
Anti-soiling coatings	TRL 3	TRL 5
Dust barriers	TRL 3	TRL 5
Soiling detectors	TRL 3	TRL 6
Ultrasonic cleaner	TRL 3	TRL 5
Gravity lip system	TRL 3	TRL 5

WASCOP materials flow diagram





- Scheme of heat storage on the cooling loop
- Water savings of WASCOP solution from state of art: ~4500 to 900 m^3/day for 50 MWe CSP plant

WASCOP: Cooling

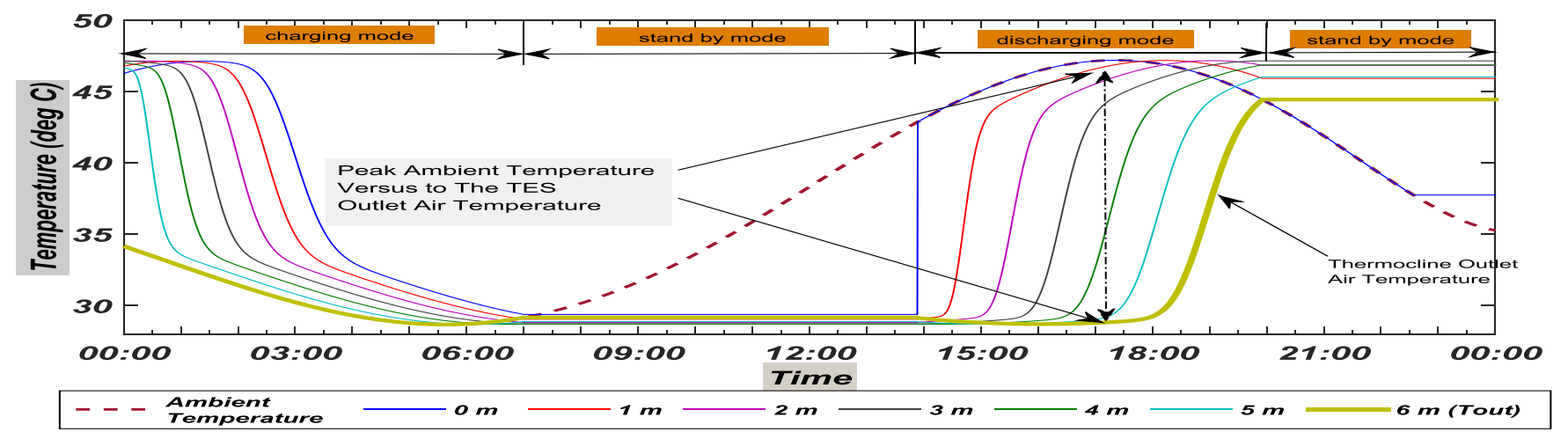
- Development of innovative versatile cooling systems
  - Increasing the efficiency vs water consumption
- Optimisation of the cooling process
- Development of advanced operating strategies for a hybrid wet/dry cooler—low cost

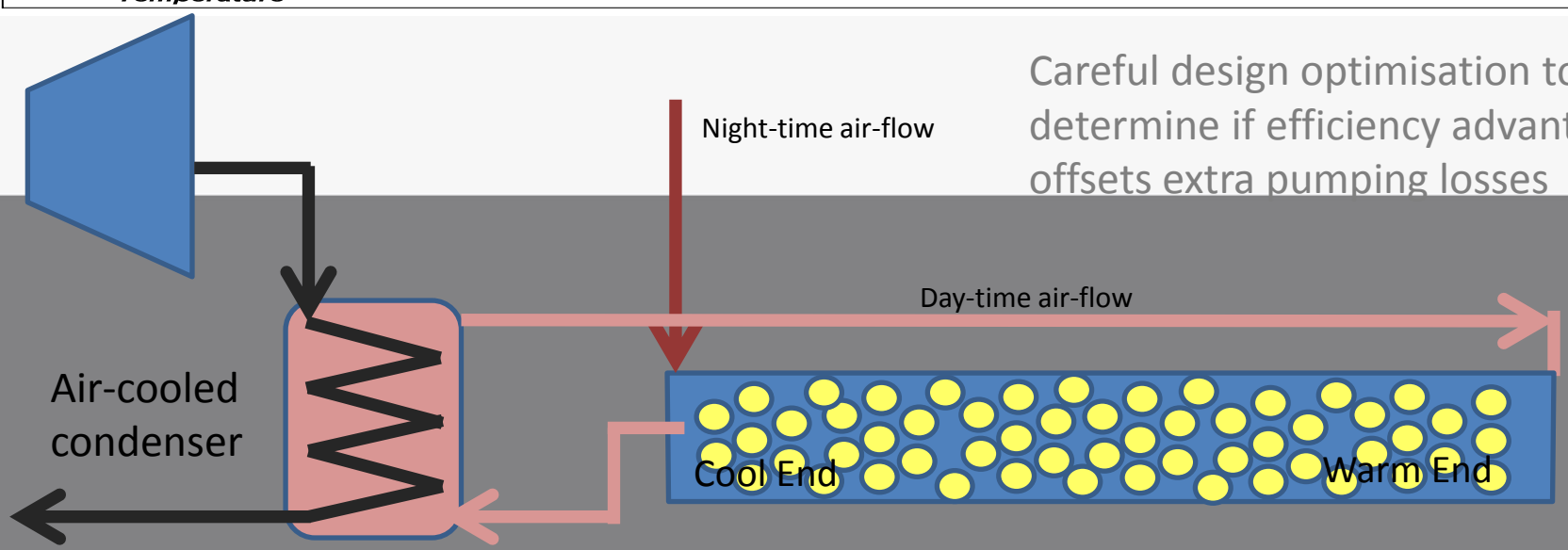
- Analysis of the current CSP plant water consumption and concrete cases

Nocturnal thermal storage: air-rock thermocline

Ergun equation

$$\Delta P = \frac{L\,G^2}{\rho_f D_s}\left(1.75\frac{1-\varepsilon}{\varepsilon^3} + 150\frac{(1-\varepsilon)^2}{\varepsilon^3}\cdot\frac{\mu}{G\,D}\right)$$





Careful design optimisation to determine if efficiency advantage offsets extra pumping losses

Spotlight on Renewable Heat Incentive

New scheme offers cash incentive to households using renewable heating systems in their homes

From: Department of Energy & Climate Change and The Rt Hon Gregory Barker MP
History: Published 9 April 2014
Part of: Increasing the use of low-carbon technologies, Climate change and Energy

The domestic Renewable Heat Incentive (RHI) launched, offering homeowners payments to offset the cost of installing low carbon systems

A new and innovative Government scheme launched today will pay people for the green heat they generate for their homes.

The domestic Renewable Heat Incentive (RHI) is the world's first long-term financial support programme for renewable heat, offering homeowners payments to offset the cost of installing low carbon systems in their properties.

Technology	Tariff
Air-source heat pumps	7.3p/kWh
Ground and water-source heat pumps	18.8p/kWh
Biomass-only boilers and biomass pellet stoves with integrated boilers	12.2p/kWh
Solar thermal panels (flat plate and evacuated tube for hot water only)	19.2 p/kWh

Any Questions???

Kumar Patchigolla
Lecturer in Carbon Capture and Storage
School of Energy, Environment and Agrifood
Email: k.patchigolla@cranfield.ac.uk