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# Effects of Biosolids Carbon Sequestration on Energy Footprint at Wastewater Treatment Plants

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# Introduction



- Most wastewater treatment processes are energy intensive and emit, directly and indirectly, greenhouse gases (GHGs).
- Due to emerging concerns with climate change and GHGs emission, it is therefore critical to understand and minimize the carbon- and energy- footprint for wastewater treatment processes.
- Carbon- and energy- footprint of wastewater treatment processes are correlated since energy use for wastewater treatment is recognized as a key constituent in carbon-footprint analyses.
- However, recent studies indicate that non  $\text{CO}_2$  greenhouse gas emission (i.e.,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ ) in some cases may have a comparable weight on carbon-footprint during wastewater treatment

# Introduction

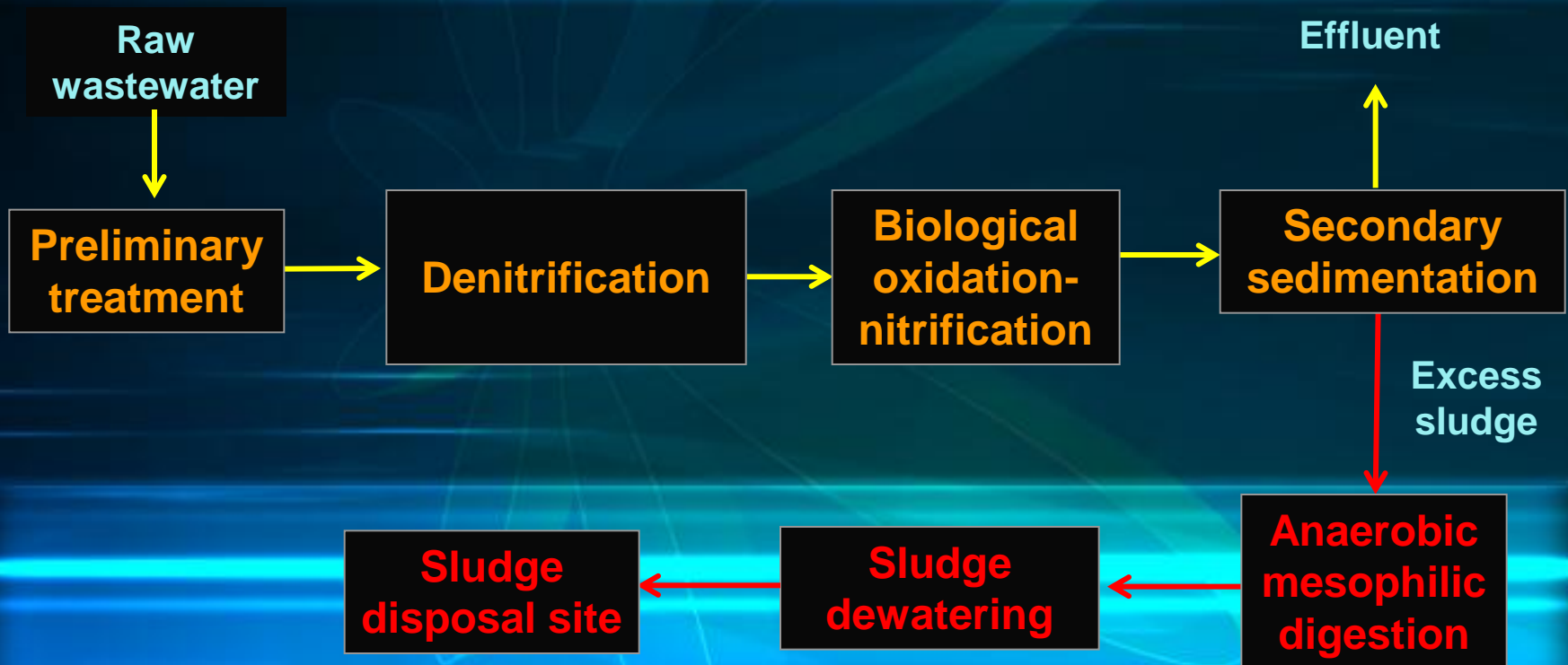


- Wastewater treatment plants' (WWTPs) greenhouses gas emission and energy consumption are affected by a great number of variables and mainly: type and sequence of biological processes adopted, pollutants load, temperature, biological process MCRT, sludge digestion process, aeration efficiency,...
- In this study we calculated the effects of MCRT (in the range 10 - 100 days) and temperature on the energy footprint (eFP) and carbon footprint (CFP) for ASP WWTP under different assumptions in terms of return rate of carbon to the atmosphere and distance of excess sludge disposal site.
- The carbon footprint (CFP) and Energy footprint (eFP) were calculated using an expansion of previously published models (Rosso and Stenstrom, 2005, 2008; Lippi et al, 2009).

# Reference plant



For this study a reference plant with a capacity of **3780 m<sup>3</sup>/d (1 MGD)** and the following treatment train was chosen.



# CFP and eFP analyses



The following contributions were considered in the CFP and eFP analyses

## CO<sub>2</sub> emission

- activated sludge respiration
- biogas combustion
- electricity production
- offset due to energy production from biogas
- transportation of sludge to disposal site
- emission at the disposal site

## Energy consumption

- aeration
- denitrification mixing
- sludge dewatering
- digester mixing and heating
- offset due to energy production from biogas

# Main assumptions



Parameter	Unit	Value
COD	mg/L	293
BOD	mg/L	150
TKN	mg N/L	60
TSS	mg TSS/L	300

## Wastewater characteristics

## Operating conditions of aerobic tank

Parameter	Unit	T = 10 °C	T = 20 °C	T = 30 °C
Aerators submergence	m	5	5	5
DO in the aerobic tank	mg/l	2.00	2.00	2.00
$\alpha$ SOTE/Z	%/m	4.00	4.00	4.00
$\alpha$ SOTE (DO corrected)	%	12.97	15.59	18.58

## VSS reduction, biogas production and characteristics

$$\text{VSS reduction} = 13.7 \cdot \text{LN}(\text{Digester SRT}) + 18.9$$

CH4 in biogas	Fraction	0.65
Specific biogas production of secondary sludge	Nm <sup>3</sup> /kgVSS	0.75

# Main assumptions



The emission of biosolids transportation and the specific  $\text{CO}_2,eq$  production for unit energy ( $\text{kgCO}_2/\text{kWh}$ ) were estimated according to the methodology in Rosso and Chau (2009).

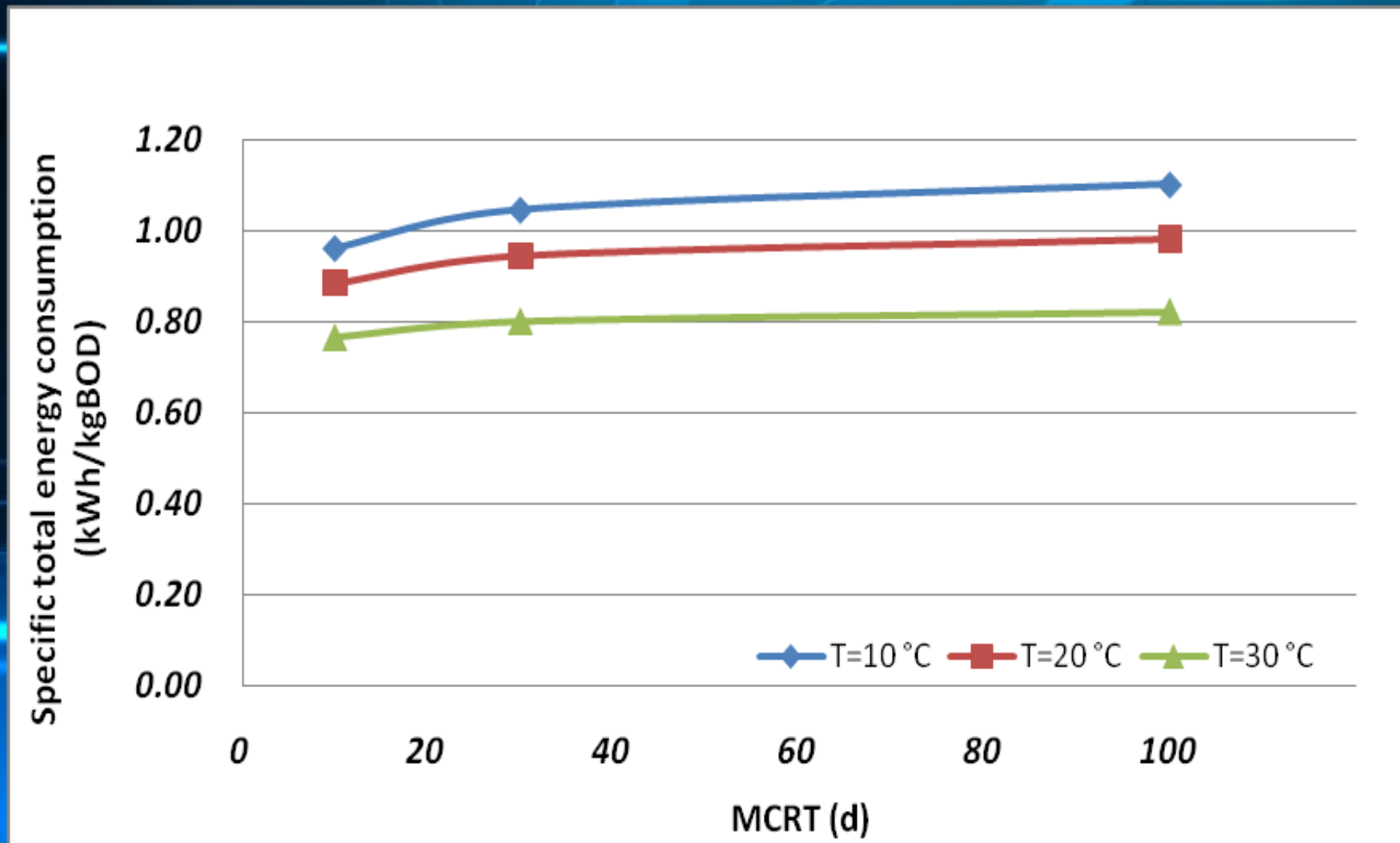
The effect of MCRT and temperature on CFP was analyzed for the following values of distance between the WWTP and the sludge disposal site: 50 km and 500 km, representing all scenario from local up to very long distance of sludge disposal site.

For carbon sequestration potential in biosolids we considered different time-scales for carbon return to the atmosphere:

- incineration (hours)
- landfill (many years).

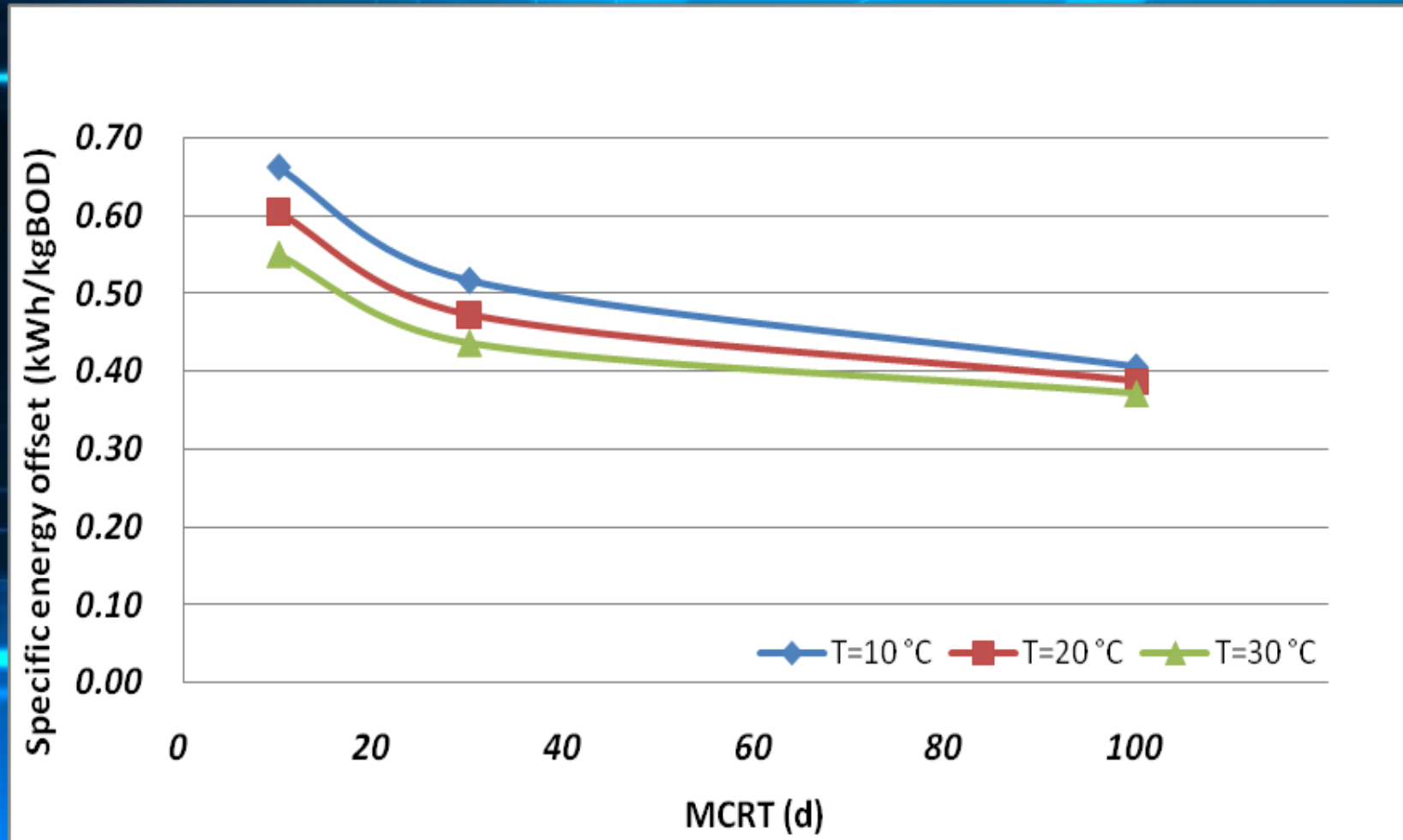
# Total energy consumption

**Specific total energy consumption  
(aeration + dewatering + digester heating and mixing)**



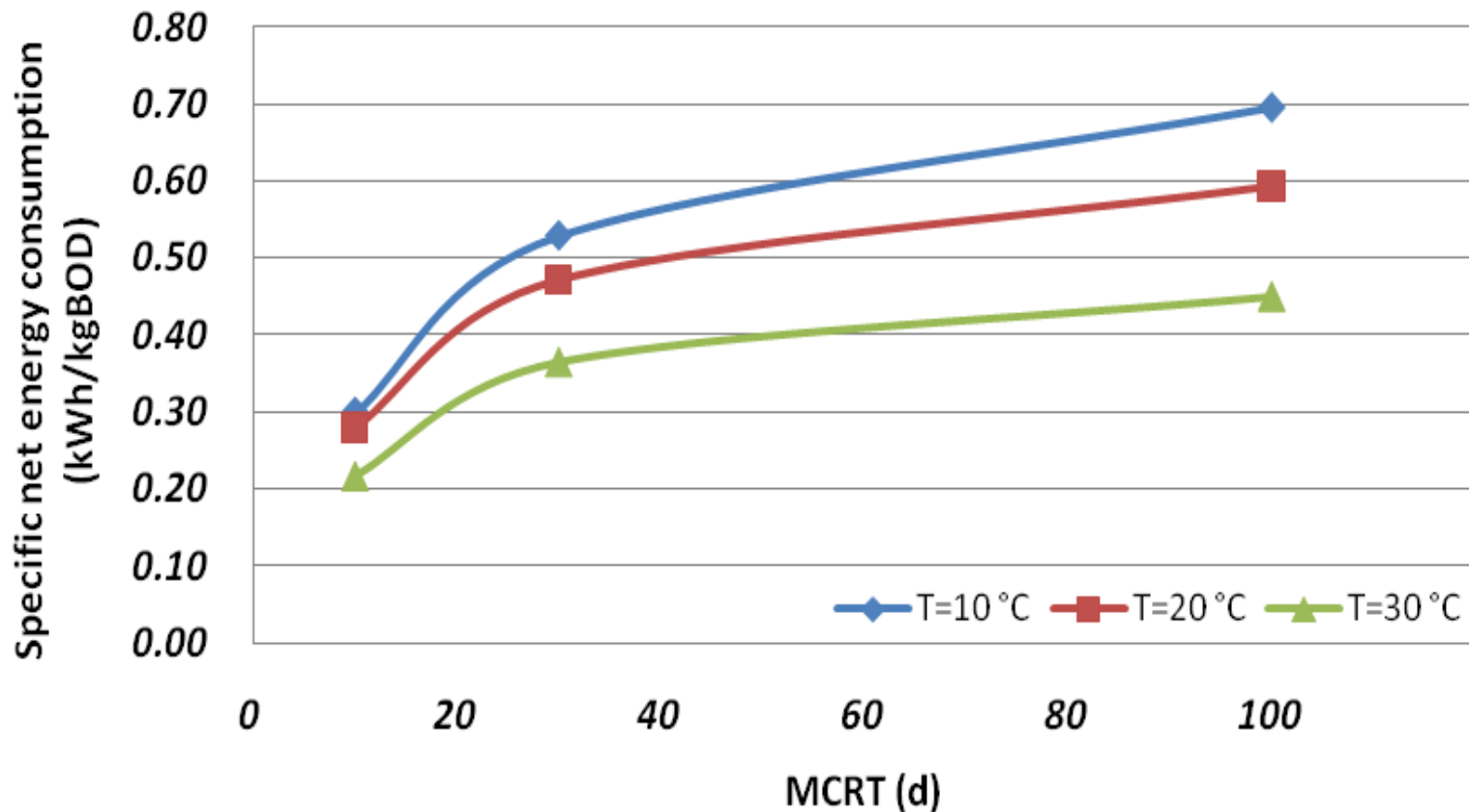
# Energy offset

## Specific energy offset from combustion of biogas



# Total net energy consumption

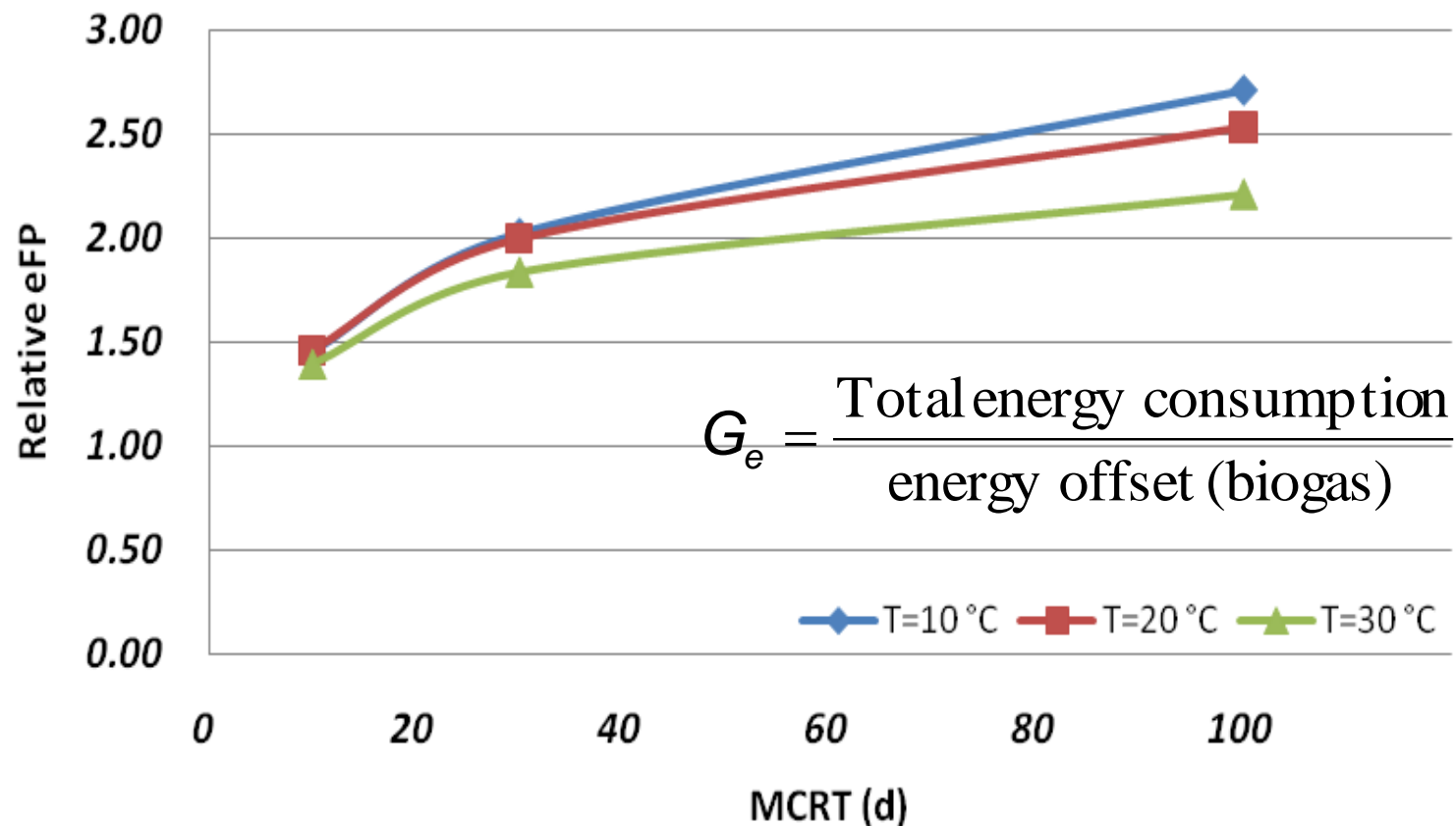
## Specific net energy consumption



# Total net energy consumption

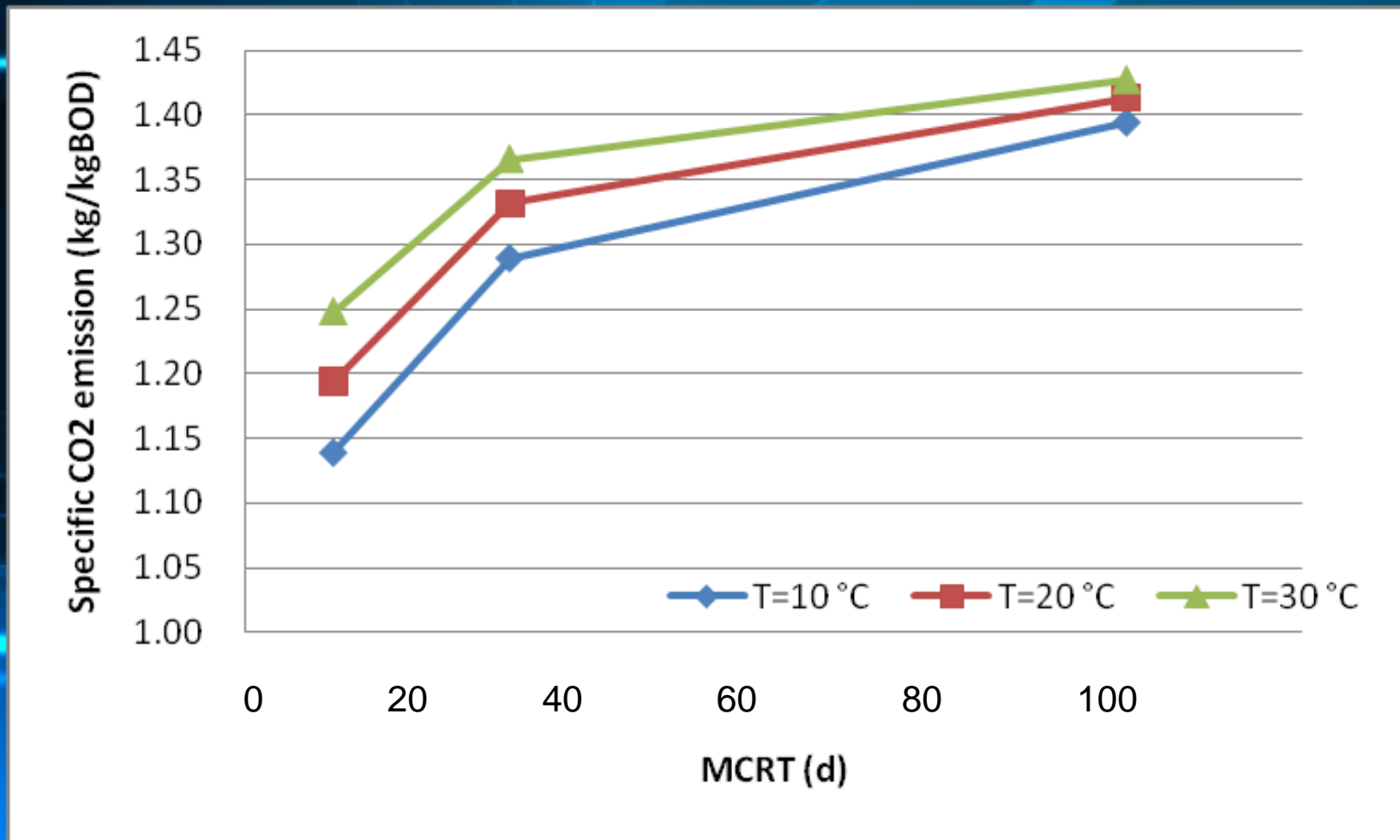


Relative eFP ( $G_e$ ) calculated as ratio between energy consumption for wastewater treatment and energy production from biogas



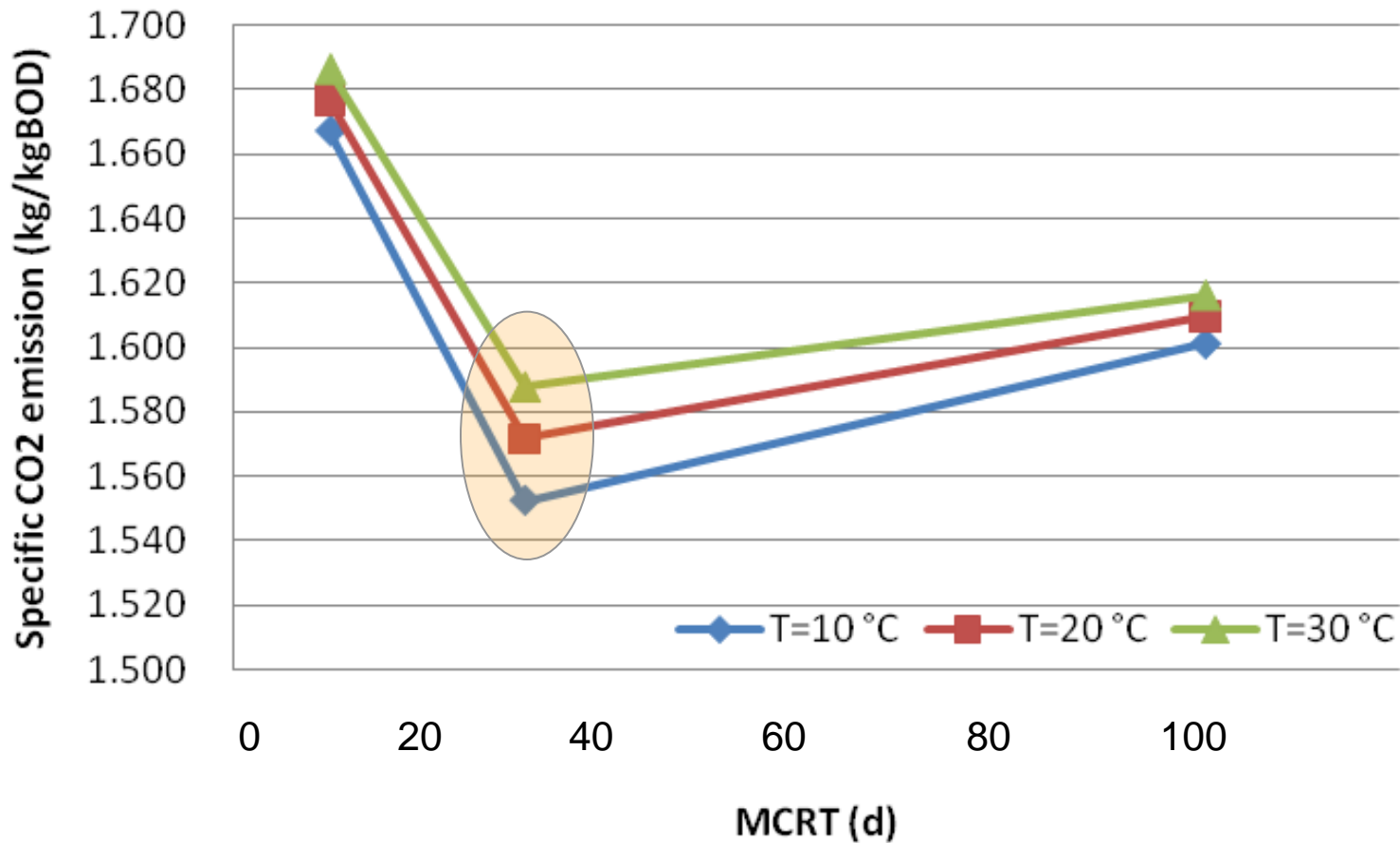
# Specific CO<sub>2</sub> emission

Specific CO<sub>2</sub> emission (kg CO<sub>2</sub>/kgBOD) due to activated sludge respiration



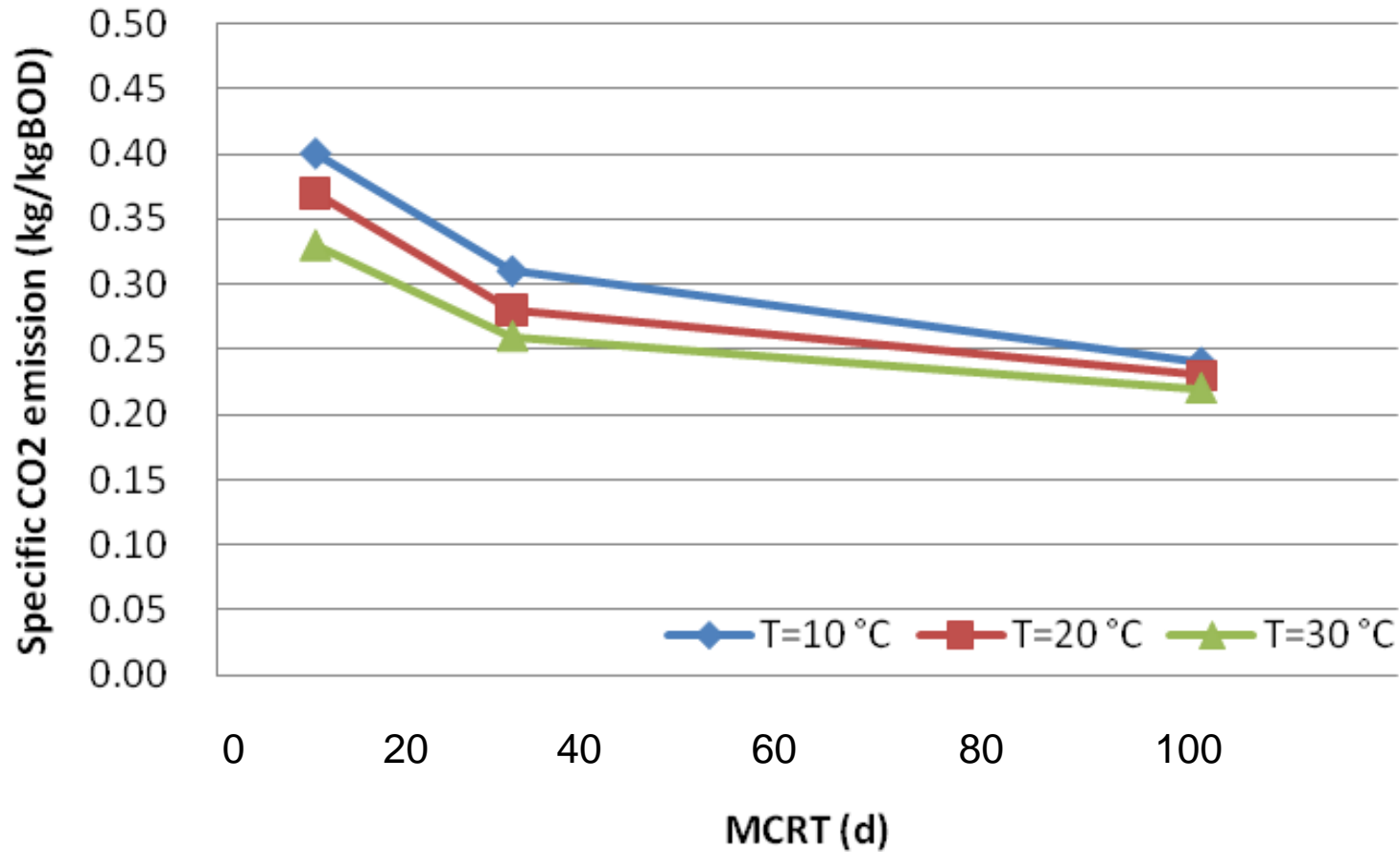
# Specific CO<sub>2</sub> emission

Specific CO<sub>2</sub> emission (kg CO<sub>2</sub>/kgBOD) due to activated sludge respiration and biogas combustion



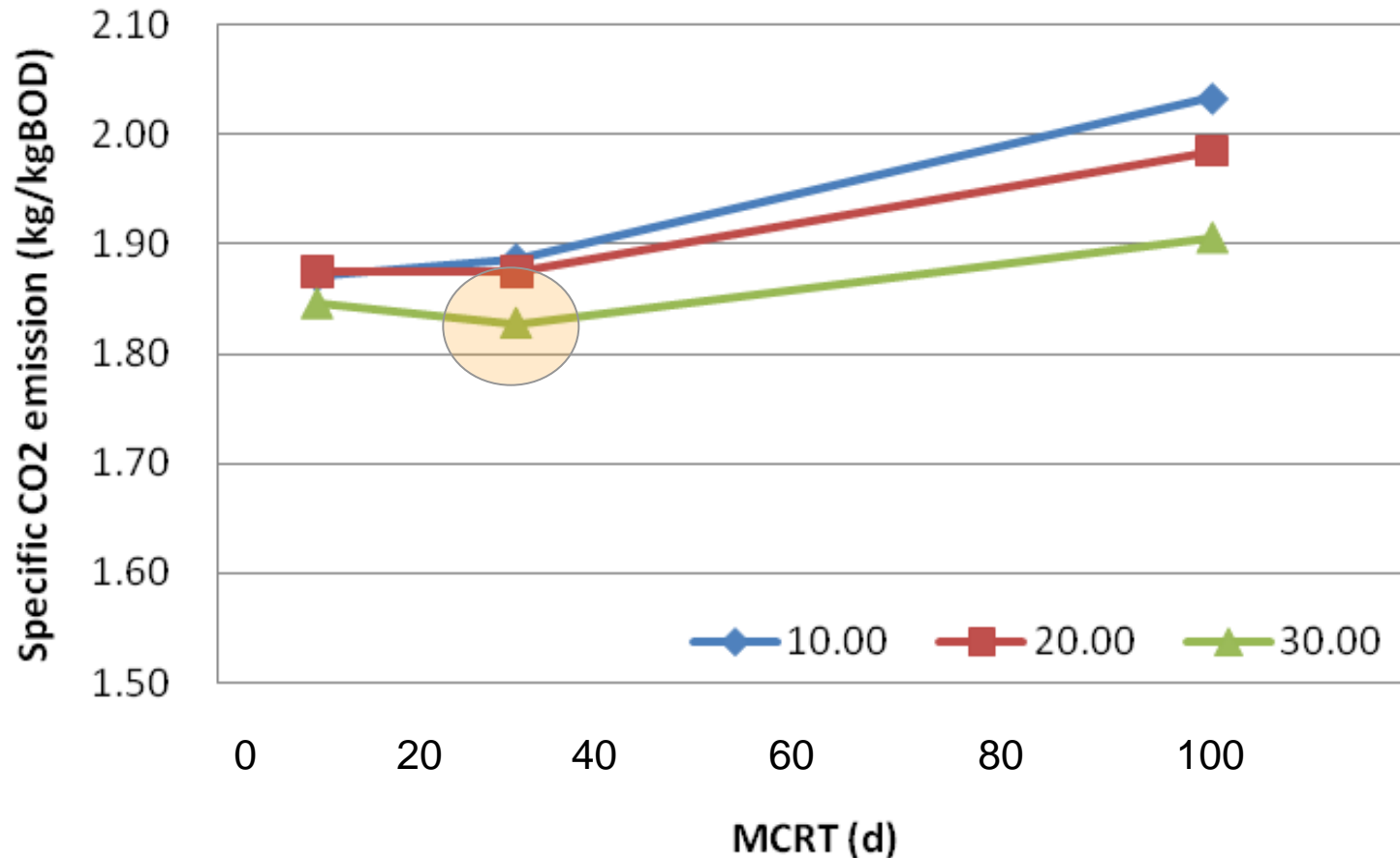
# Specific CO<sub>2</sub> emission

Total specific CO<sub>2</sub> offset (kg CO<sub>2</sub>/kgBOD) from utilization of biogas for energy production



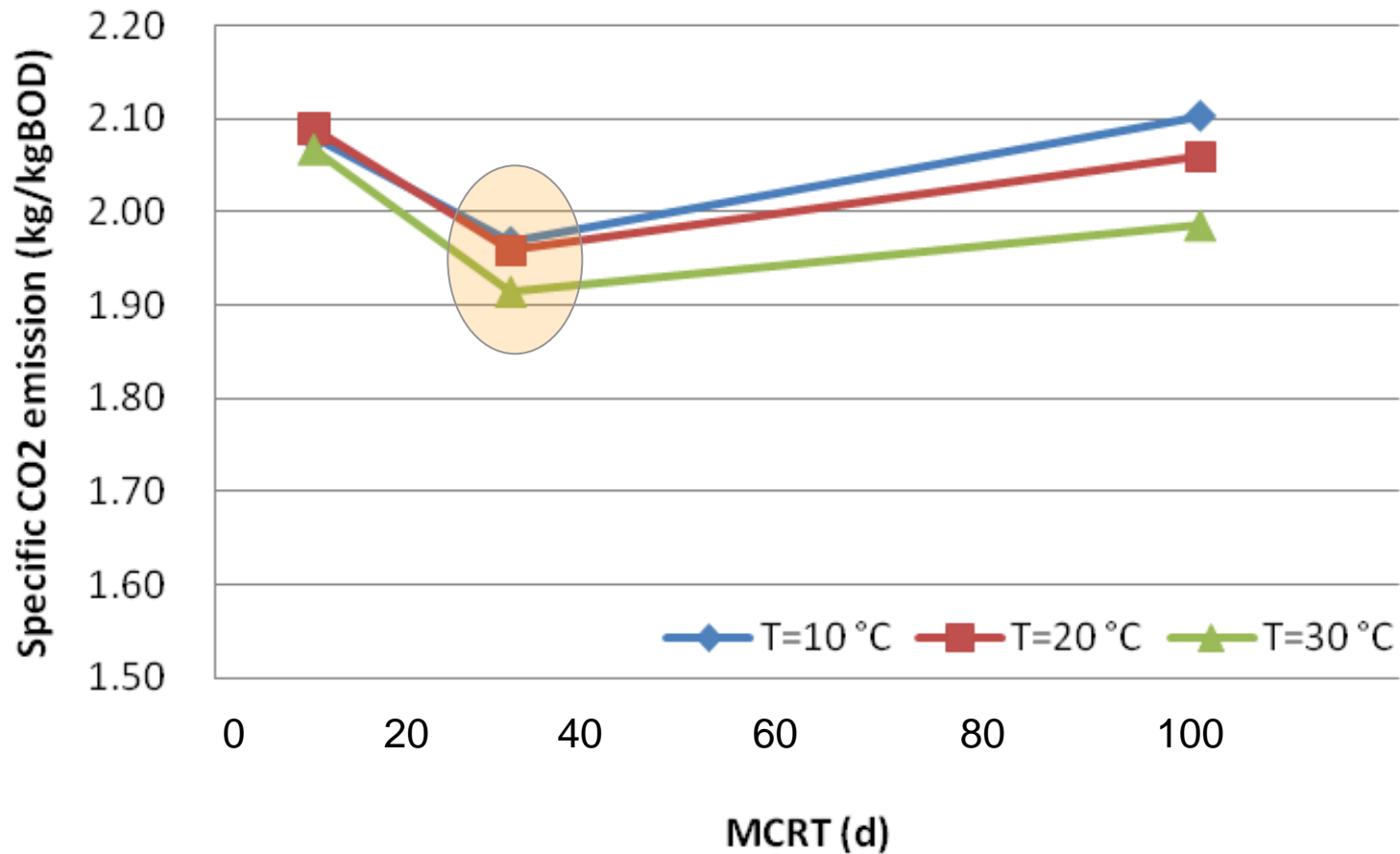
# Specific CO<sub>2</sub> emission

Total specific CO<sub>2</sub> emission (kg CO<sub>2</sub>/kgBOD) - Disposal site distance: 50 km (activated sludge respiration + biogas combustion + transportation + offset)



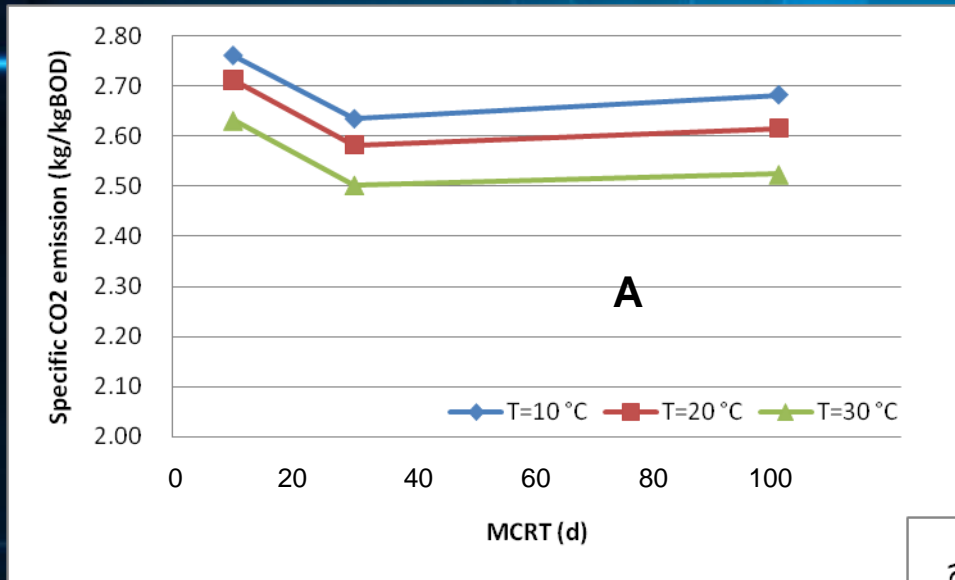
# Specific CO<sub>2</sub> emission

Total specific CO<sub>2</sub> emission (kg CO<sub>2</sub>/kgBOD) - Disposal site distance: 500 km (activated sludge respiration + biogas combustion + transportation + offset)

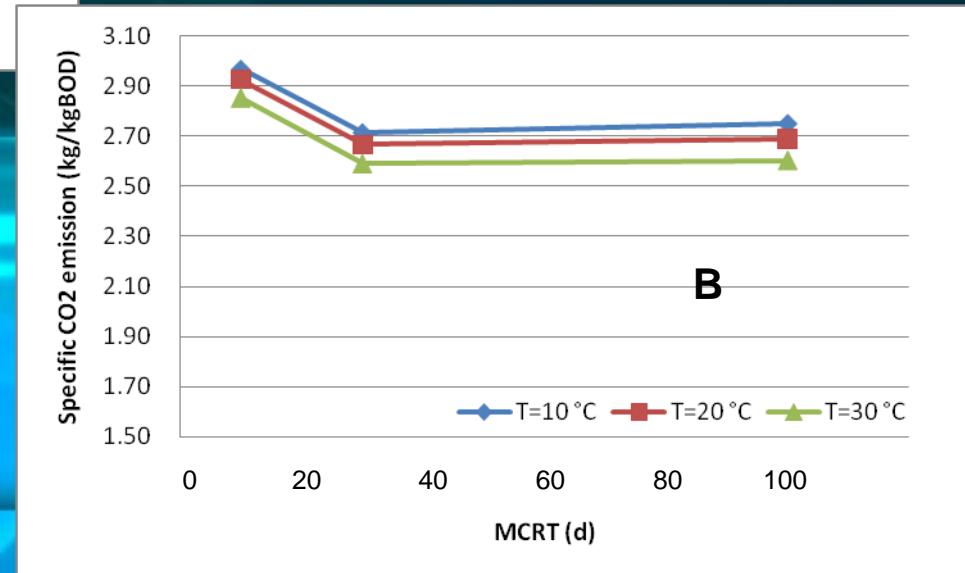


# Specific CO<sub>2</sub> emission

Total specific CO<sub>2</sub> emission (kg CO<sub>2</sub>/kgBOD) with incineration of sludge in the case of local disposal site (A) and long distance disposal site (B).



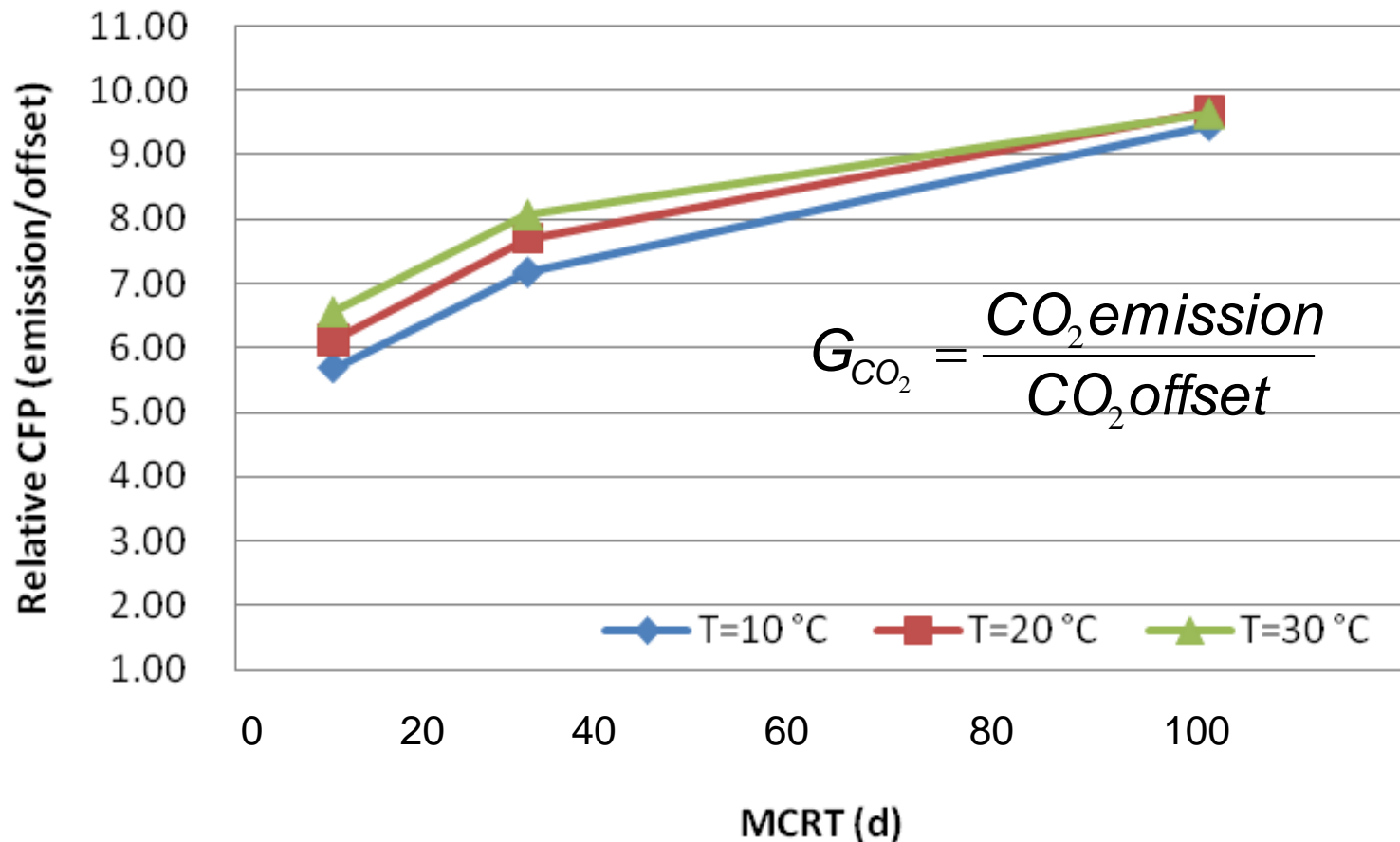
(activated sludge respiration + biogas combustion + transportation + offset + emission from sludge incineration)



# Relative CFP



Relative CFP ( $G_{CO_2}$ ) calculated as ratio between  $CO_2$  emission and  $CO_2$  offset from biogas combustion for energy production (disposal site distance: 50 km)



# Emission of other GHGs



**The specific CO<sub>2</sub> equivalent emission due to fugitive methane and nitrous oxide (N<sub>2</sub>O) were calculated.**

**In the case of N<sub>2</sub>O we hypothesized that 1% of both nitrified and denitrified nitrogen is converted in N<sub>2</sub>O which has a GWP of 298 in 100 years.**

**The contribution of N<sub>2</sub>O emission is between 0.7 and 0.73 kgCO<sub>2</sub>eq/kgBOD and is of the same order of magnitude of CO<sub>2</sub> emission for activated sludge respiration.**

**For fugitive methane we hypothesized a loss of 2% of methane produced. The contribution is between 0.03 and 0.06 kgCO<sub>2</sub>eq/kg/BOD and is one order of magnitude lower than the other contribution.**

# Conclusions



- The energy consumption and CO<sub>2</sub> emission from WWTP as a function of MCRT and temperature were evaluated using an expansion of our previously published models.
- A WWTP of 1 MGD (3780 m<sup>3</sup>/d) consisting of headworks, nitrifying/denitrifying ASP, secondary sedimentation, mesophilic anaerobic digestion and sludge dewatering was analyzed.
- The energy consumption for aeration, dewatering, digester heating and mixing increases with MCRT between 10 and 100 d and is higher for lower temperature.
- The relative eFP (used/recovered) in the MCRT range 10-100 d is 1.5-2.2 for T = 30°C and 1.5-2.75 for T = 10°C
- Carbon footprint ranges for the same scenarios are different, as carbon fluxes and other GHG emission vary with temperature

# Conclusions



- Specific  $\text{CO}_2$  emission ( $\text{kgCO}_2/\text{kgBOD}$ ) due to activated sludge respiration and biogas combustion has a minimum for an MCRT of 30 d.
- Total specific  $\text{CO}_2$  emission ( $\text{kg CO}_2/\text{kgBOD}$ ) due to activated sludge respiration + biogas combustion + transportation - offset has a minimum for an MCRT of 30 d regardless of temperature when the disposal site is really far from the plant (500 km). The behaviour is different for small distance of the disposal site.
- The relative CFP increase from 6 to 9.5 when MCRT change from 10 to 100; in this case the effect of the temperature is limited.
- The contribution of  $\text{N}_2\text{O}$  emission on CFP (at 1% conversion) is of the same order of magnitude than activated sludge respiration.

# References



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