EPSRC Centre for
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SUSTAINABILITY

Technical Seminar Series

Communication appeals for influencing pro-environmental behaviour change

Sanober Khattak, IESD,
De Montfort University

16:00-17:00 14 May 2015

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Technical webinar series – schedule

14 MAY 2015

We will record this webinar and issue the recording afterwards

Slides will also be made available

Please use chat to raise questions throughout the presentations

Questions after this presentation finishes? Please contact

Sanober Khattak sanober.khattak@email.dmu.ac.uk

- **Today:** Resource Efficient Manufacturing: An Exergy Based Approach, Sanober Khattak, De Montfort University
- **Next :** 16:00 4th June "**Sustainable value creation in manufacturing: Understanding the contribution of maintenance function**" Maria Holgado, IfM, University of Cambridge
- Future months: much more to follow!!
- Typically first Thursday of the month

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Technical webinar series – the aims

14 MAY 2015

- Sharing **research** results and **industrial** practice for Centre members
- **Connecting people** within the Centre as well as outside the Centre
- Providing **feedback**, comments, suggestions, refinement, etc to those presenting

If you have interesting content to share from research and development, good practice, valuable results in practice, etc then perhaps you should be scheduled in the series.

*Contact **Sharon Mey** cis-admin@ eng.cam.ac.uk*

*or **Peter Ball**, p.d.ball@cranfield.ac.uk*

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How is the Centre structured?

Eco-efficiency

Reducing resourse use (water, energy, materials)

Improvements without radical changes to product or process

Eco-factory

Increasing added value and improving production capability and responsiveness

Decreasing consumption of natural resources

Sustainable Industrial System

Exploring future configurations of the industrial system and their implications

Taking first steps to improve understanding of the long term challenges facing industry

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How the Centre works - Impact

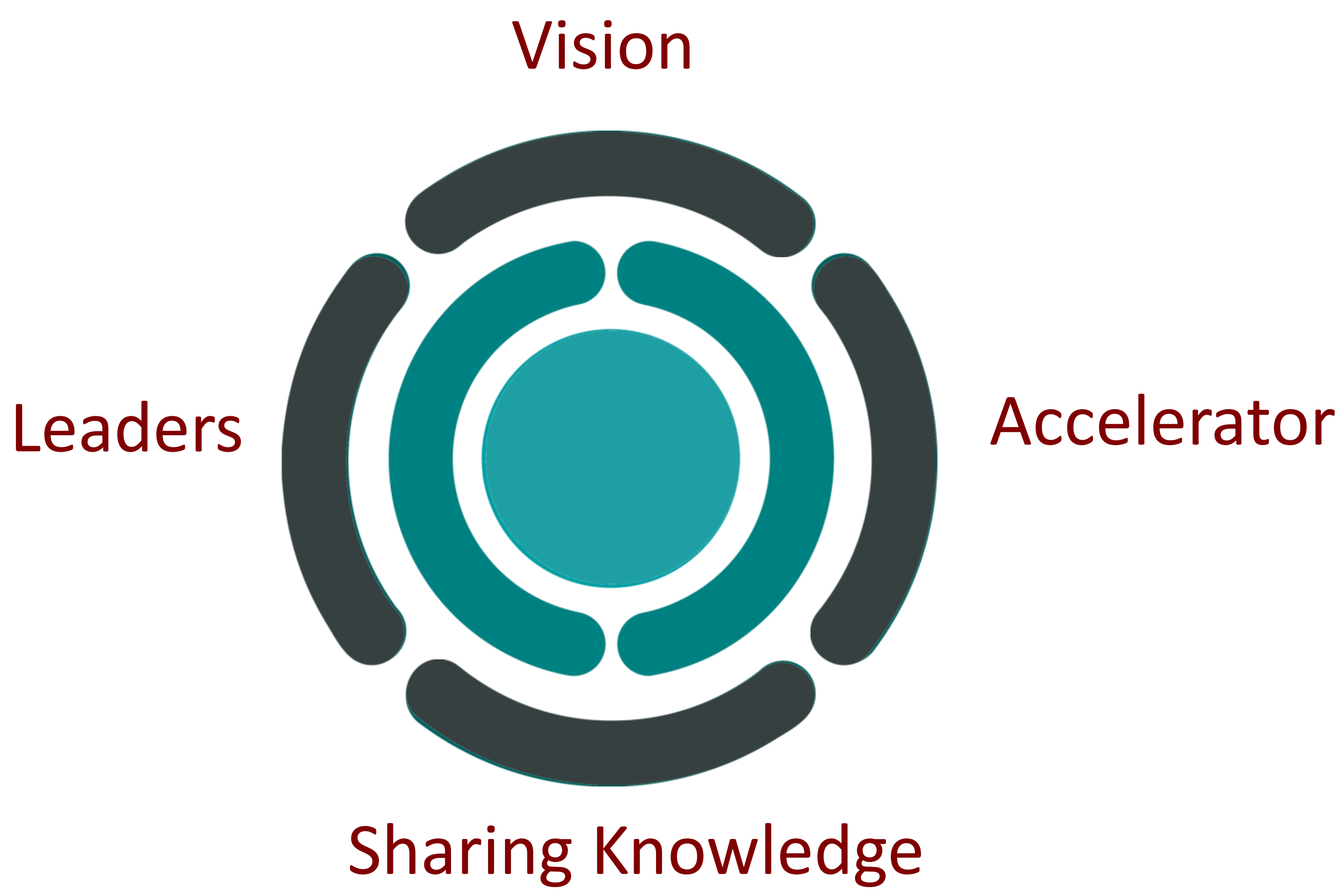
WEBINARS … CONTRIBUTING TO SHARING OUR KNOWLEDGE

Educating the
Leaders of
Tomorrow
TODAY

Bigger **Impact**,
faster, wider,
sooner

Sharing **Knowledge**

Building & Sharing
a **Vision**



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Eco-Efficiency Grand Challenge: Resource Efficiency in the Factory

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16.00 **Introduction** (Peter)

16.10 **Resource efficient manufacturing – An Exergy Approach** (Sanober)

16.40 **Q&A** (Sanober)

16.50 **Wrap up** (Peter)

17.00 Close

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What is exergy?

- System property based on the 1st and 2nd law of thermodynamics
  - Useful work potential of a system
- Quantity and quality of mass and energy
- Variation from a reference condition
- Consumable (useful for resource accounting)

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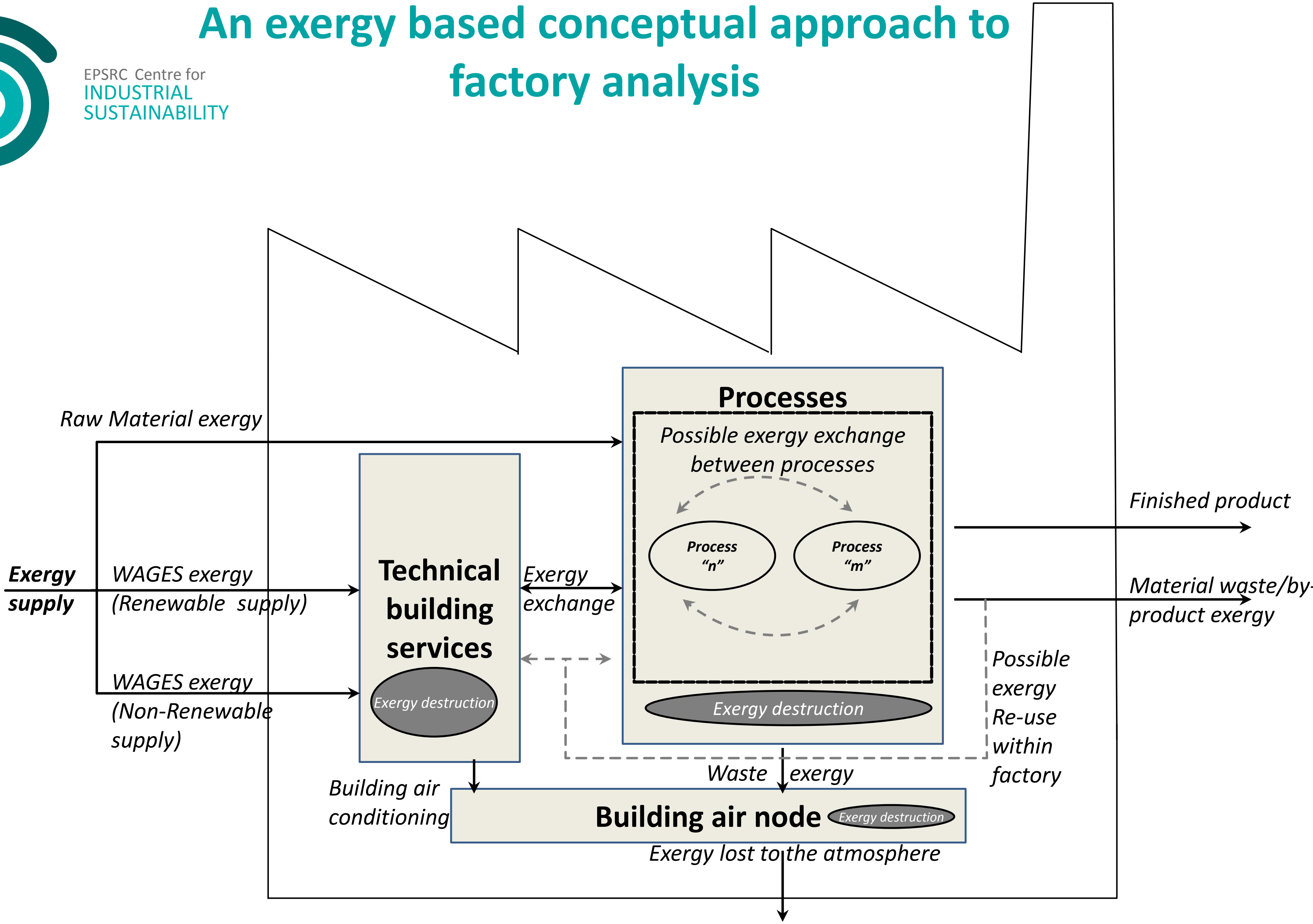
Understanding the quality of energy

	D (long life)battery	Coffee at 60°C
Energy	=15 Wh =54 kJ	Mass of coffee = 250g Specific heat capacity = 4.172 kJ/kgK Temperature = 60°C = 333K $Energy = mcT = 368kJ$
Exergy	=54 kJ	$Exergy = Q\left(1 - \frac{T_0}{T}\right) = 38.6kJ$

Forms of exergy

Exergy					
Physical				Chemical	
Mechanical		Thermo-mechanical		Chemical reaction	Mixing and separation
Kinetic	Potential	Pressure based	Temperature based		

An exergy based conceptual approach to factory analysis



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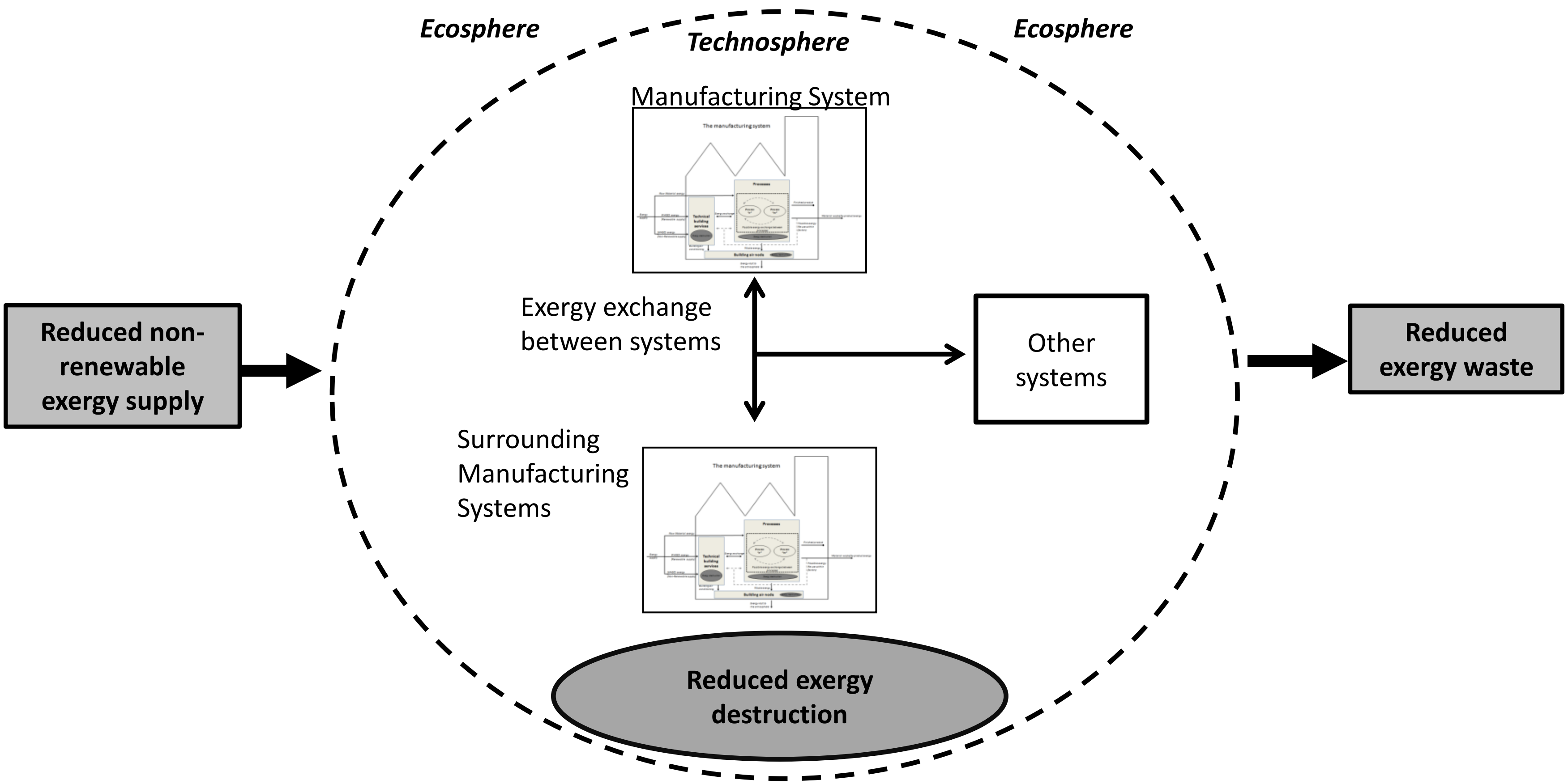
Higher Level Perspective



Case study – Factory heat reuse

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- Automotive cylinder head manufacturing line
- HVAC system analysis
- Resource consumption quantified through exergy approach
- Results from energy and exergy approaches compared
- Simulation based approach to compare technology options

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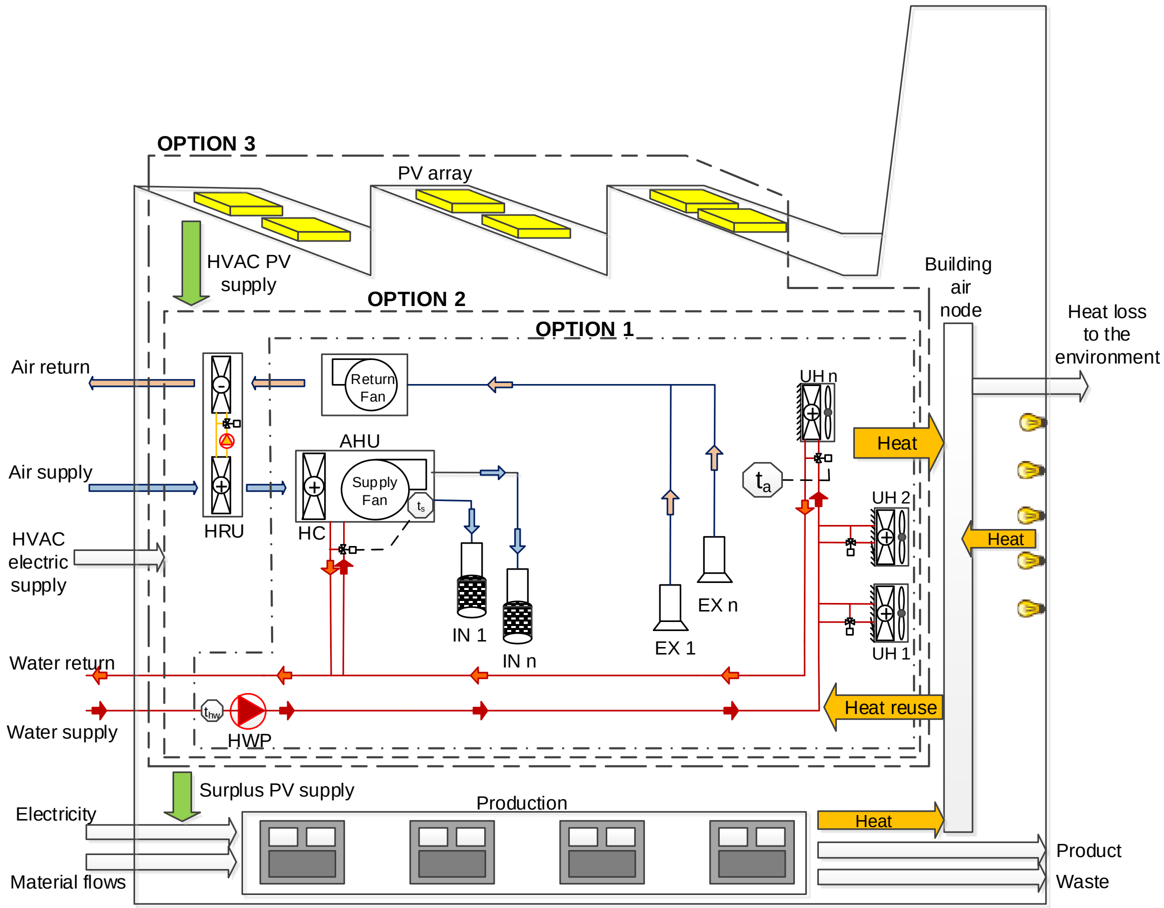
Control Volume depicting the factory



Option 1:
No heat recovery

Option 2:
With heat recovery

Option 3:
With heat recovery and renewable supply

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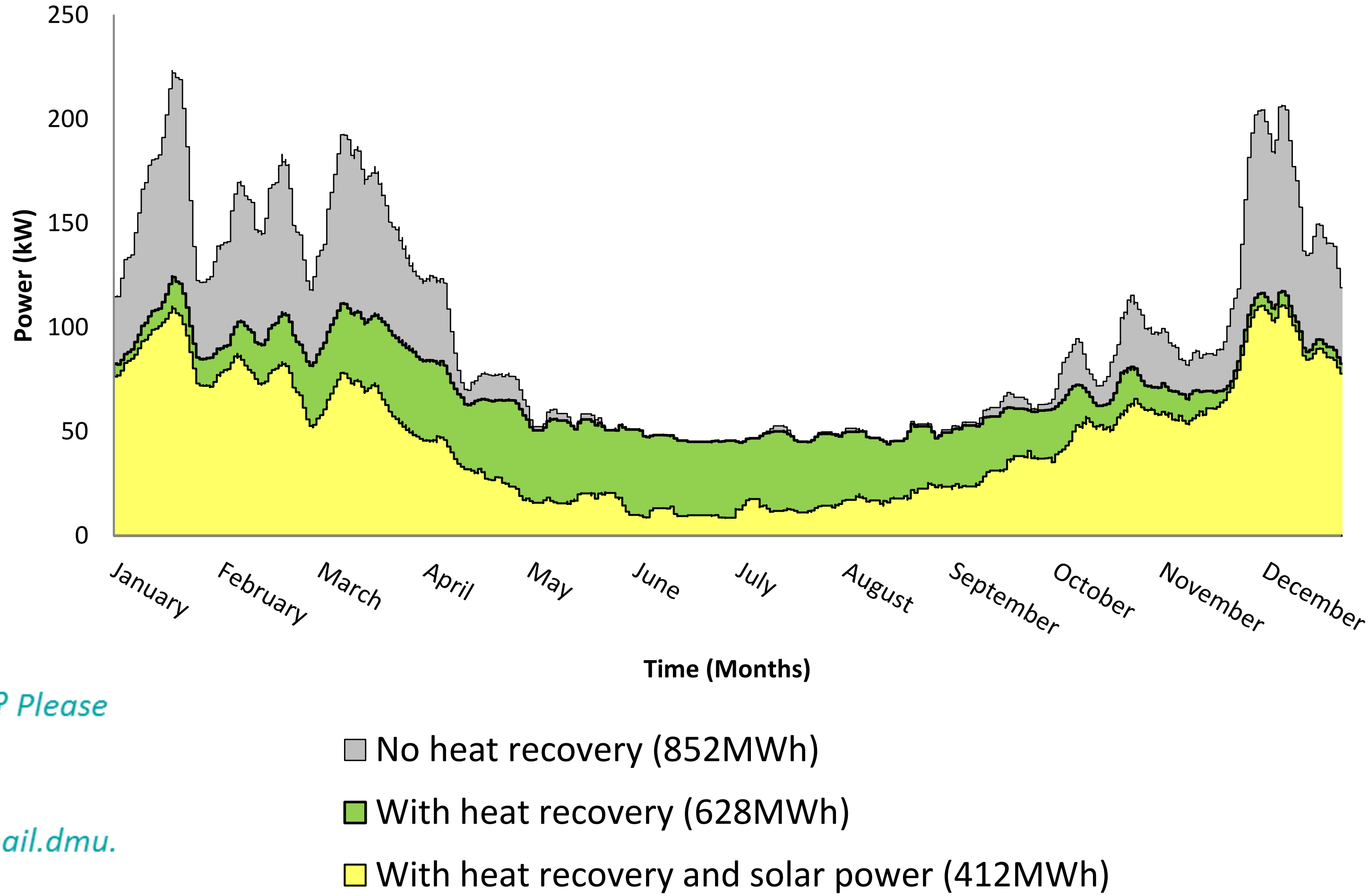
HVAC non- renewable exergy demand



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Summary of yearly results

	Non-renewable energy demand (MWh/year)	Non-renewable exergy demand (MWh/year)	Non-renewable exergy destruction (MWh/year)
Option 1 -No heat recovery	2962	851	732
Option 2 – With heat recovery	1329 (55% of opt. 1)	627 (26% of opt. 1)	581 (21% of opt. 1)
Option 3 – With heat recovery and solar power	1118 (62% of opt. 1)	412 (52% of opt. 1)	361 (49% of opt. 1)

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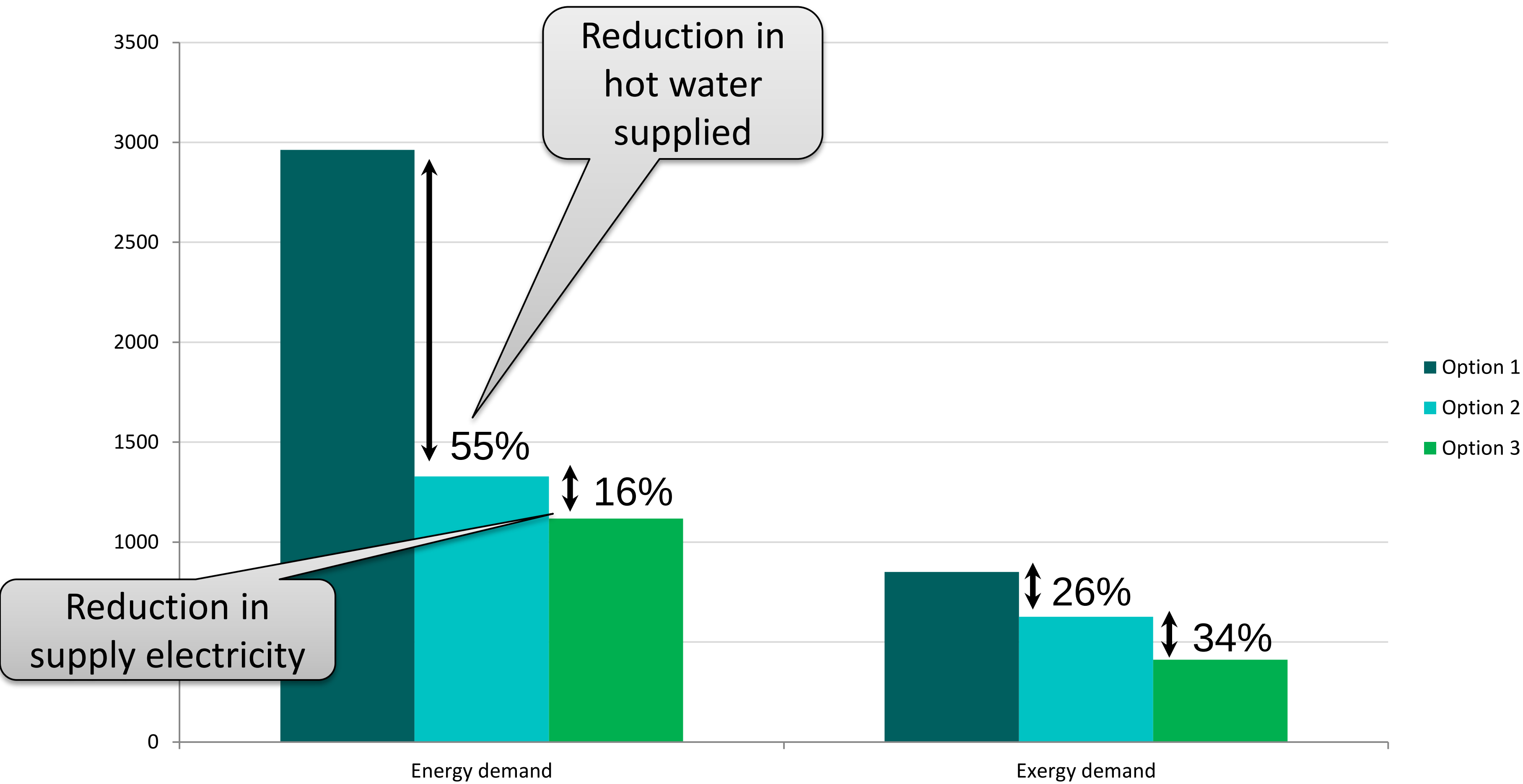
Comparison of results from the energy and exergy approach



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Summary

- Resource consumption quantified
- Low grade heat is reused to offset higher grade energy.
- Energy quality supply-demand matching improved.
- Data requirements
- Low level of complexity in exergy calculations

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Jaggery Production – A Renewable Fired Furnace Case Study

What is jaggery?

- A sugar-cane based product
- Brown sugar blocks

The analysis required:

- Mass balance
- Energy balance
- Exergy analysis

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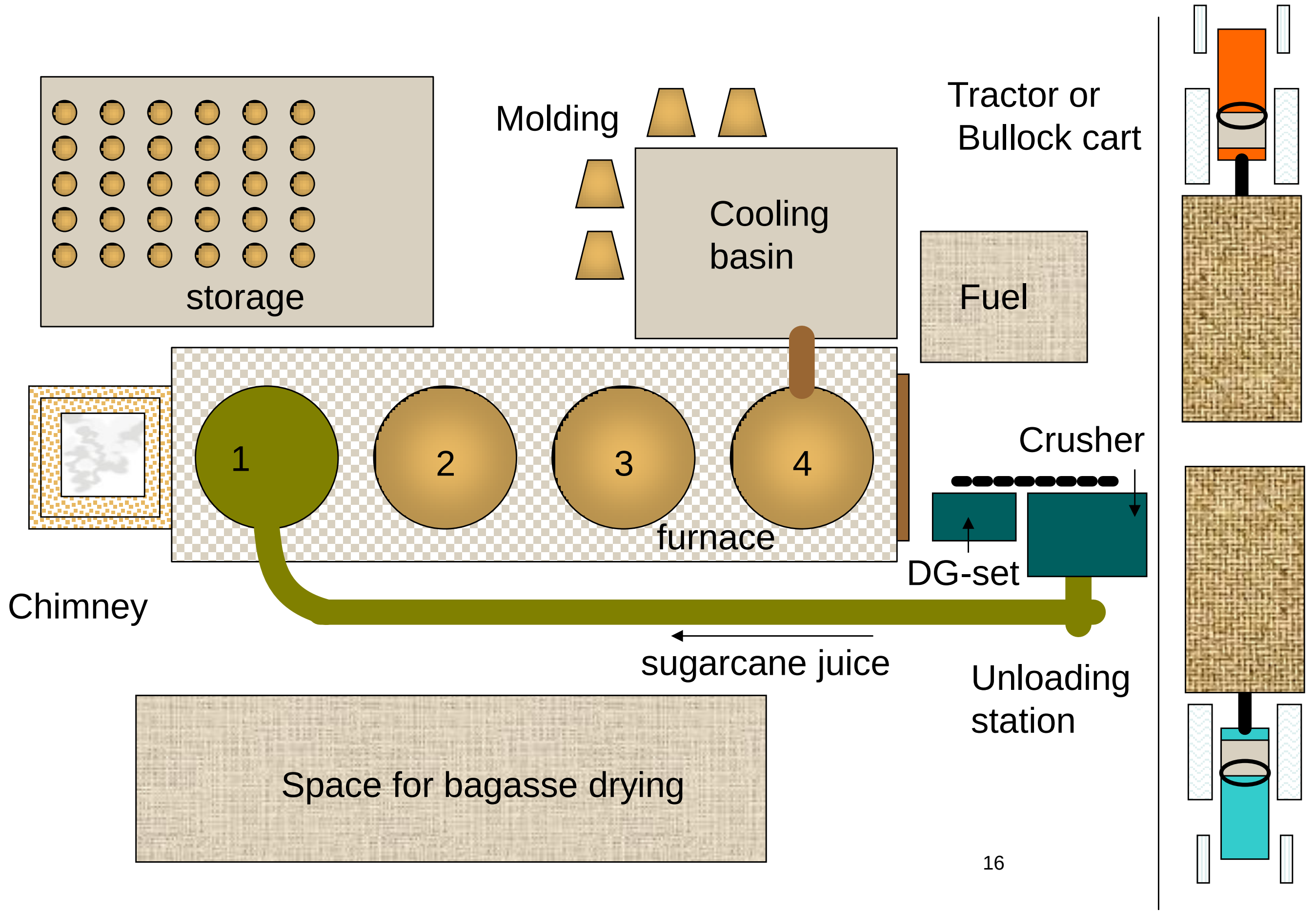
Four Pan Plant Layout



([Sardeshpande et al., 2010](#))

Furnace Cross-Section

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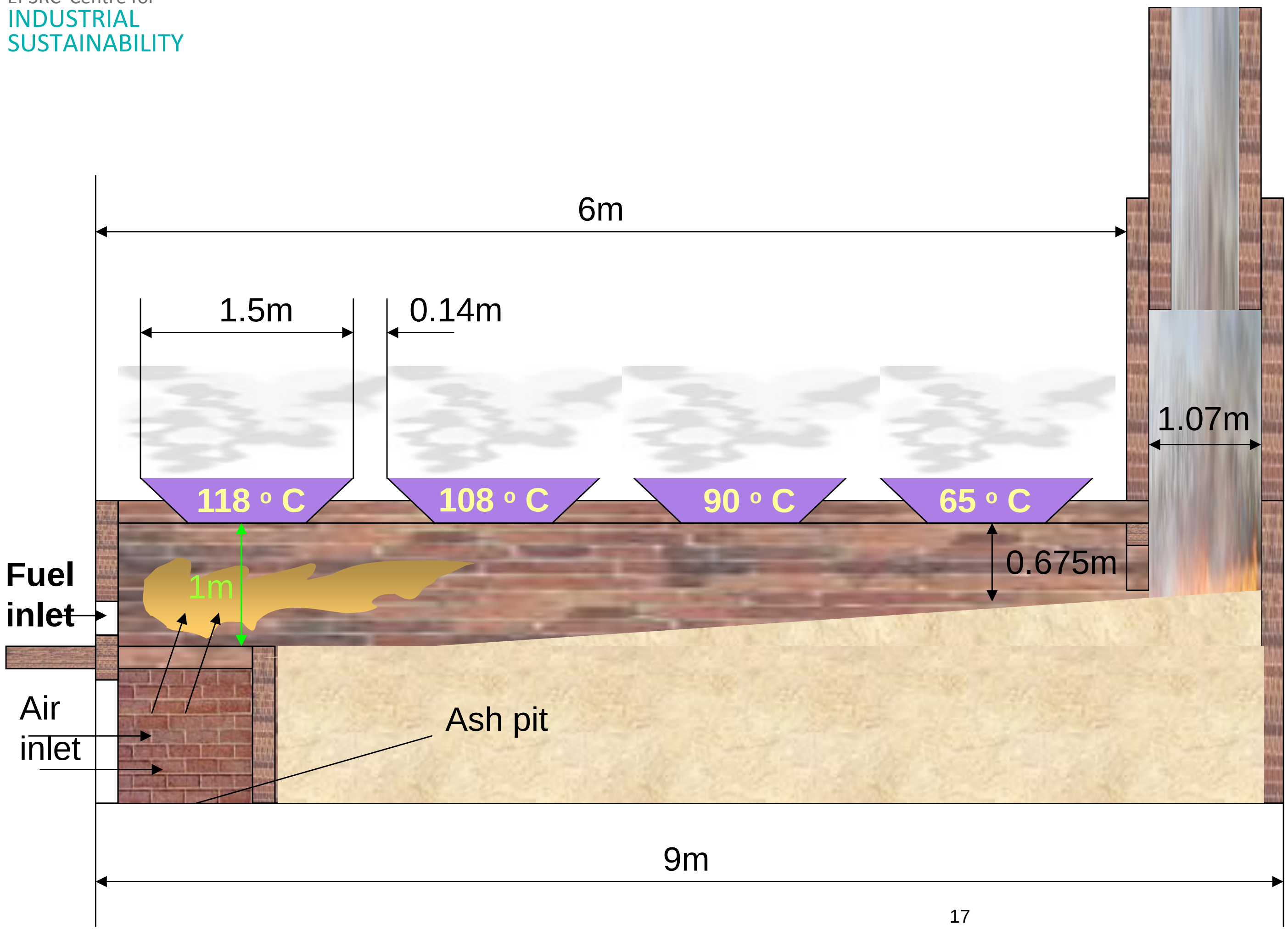

(Sardeshpande et al., 2010)

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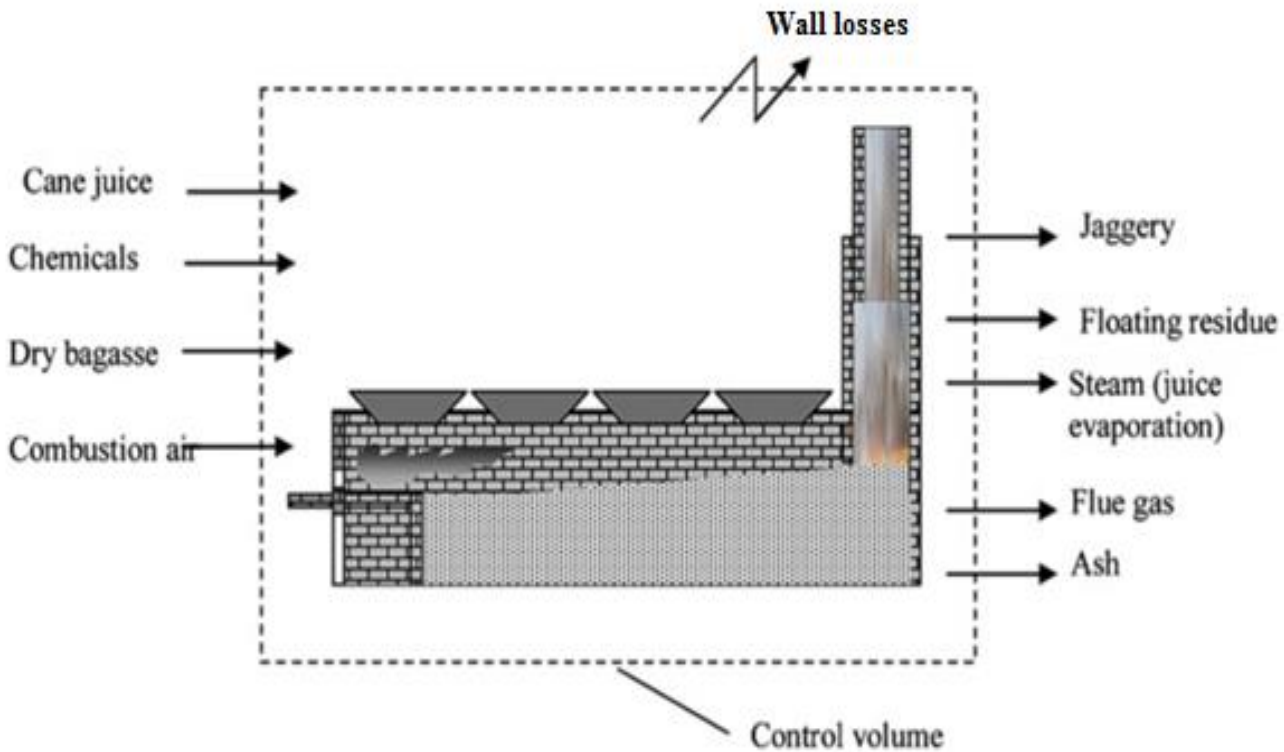
The Exergy Balance



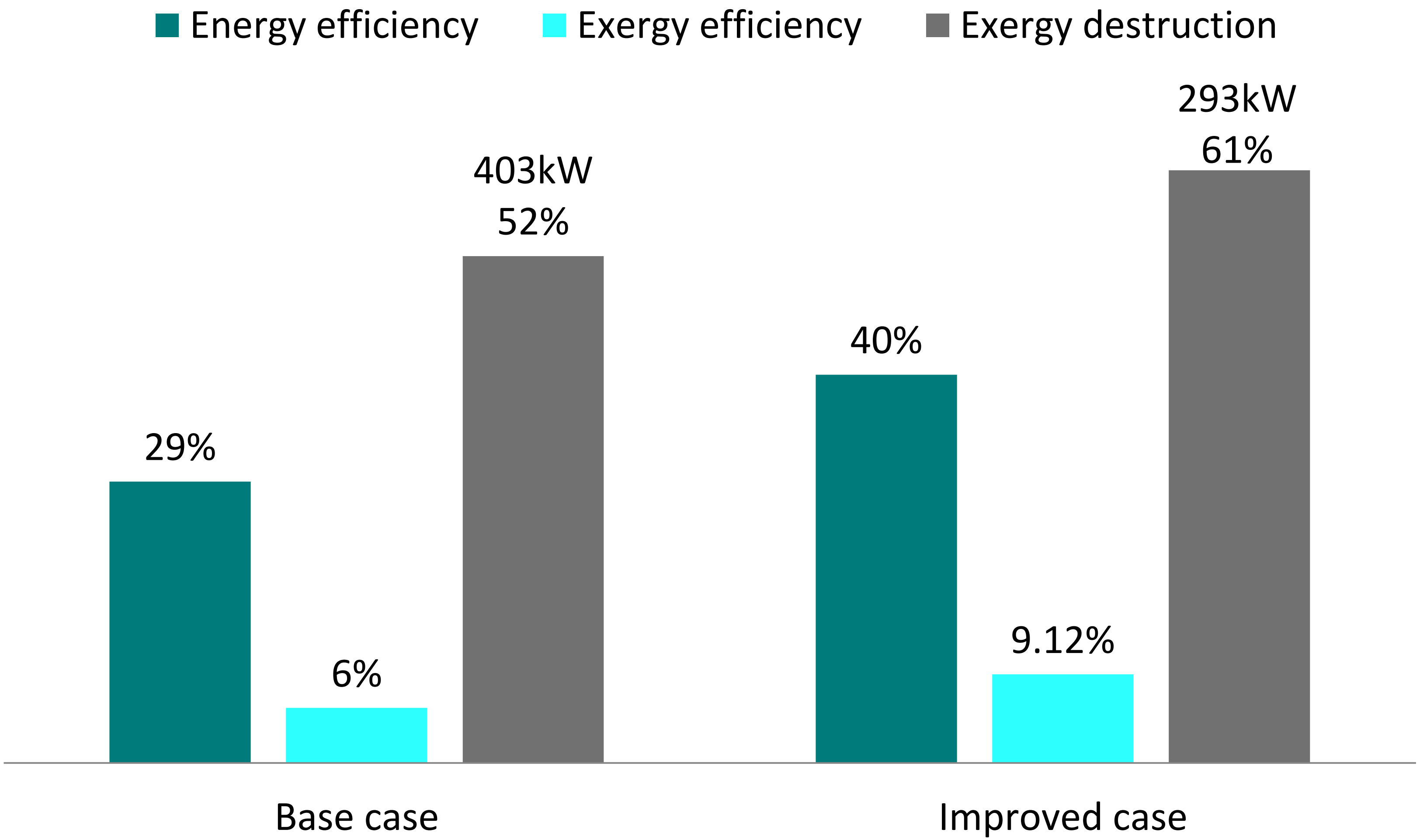
After [Sardeshpande et al., 2010]

$$Exergy\ IN = Exergy\ OUT + Exergy\ destruction$$

$$Ex_{juice} + Ex_{bagasse} =$$

$$Ex_{jaggery} + Ex_{flue} + Ex_{wall\ losses} + Ex_{ash} + Ex_{vapour} + Ex_{dest}$$

Combustion efficiency and exergy destruction



Effect of modification on symbiosis

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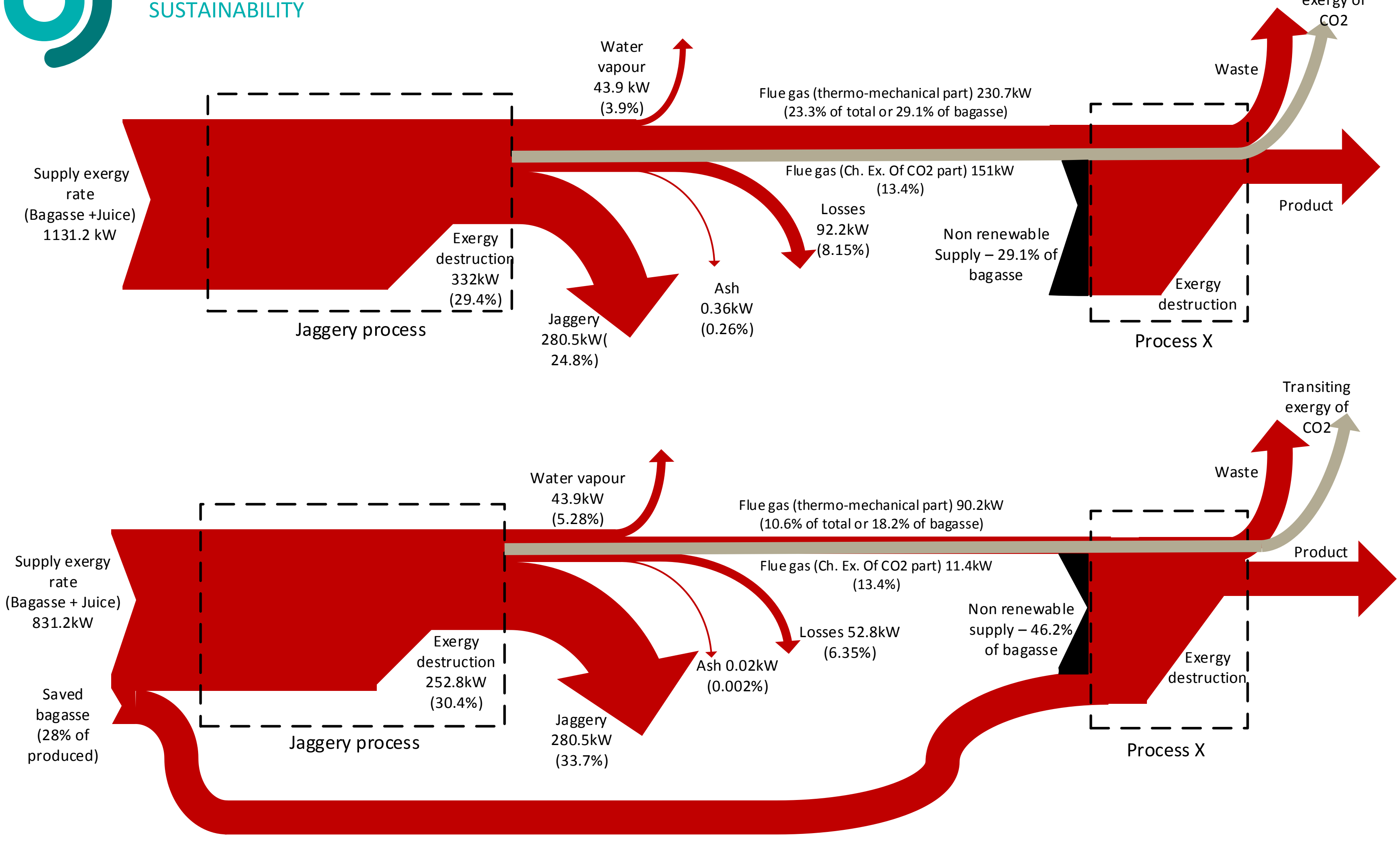

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Water Reuse – A Food Factory Case Study

- 27/4 Production
- Processes and machinery (Oven, mashing, cleaning, washing etc.)
- Resources supplied to the factory

Year	Gas(kWh)	Electricity (kWh)	Water(m^3)
2012	679,290	224,898	3335
2013	728,257	224,351	3542
2014	737,920	204,434	3510

(Fuentes, 2014)

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Total exergy of a mass flow

$$b_T(\mathrm{kJ/kg}) = \underbrace{c_{p,\mathrm{H_2O}}\left[T_p - T_0 - T_0\ln\left(\frac{T_p}{T_0}\right)\right]}_{b_t} + \underbrace{v_{\mathrm{H_2O}}(p_p - p_0)}_{b_m}$$

$$+ \underbrace{\left[\sum_i y_i\left(\Delta G_f + \sum_e n_e b_{\mathrm{chne}}\right)_i\right]_p}_{b_{ch}}$$

$$+ \underbrace{RT_0\sum x_i \ln\frac{a_i}{a_0}}_{b_c} + \underbrace{\frac{1}{2}\left(\frac{C_p^2 - C_0^2}{1000}\right)}_{b_k} + \underbrace{g(z_p - z_0)}_{b_z}$$

Chemical form
reaction exe

Concentration exergy

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Method of Chemical Exergy Calculation for the water sample

- Inorganic and Organic substances present.
- Different methods for organics calculation.
- Tests conducted :
  - Electrical conductivity
  - COD (Oxygen demand)
  - TDS (Total dissolved solids)
  - Anions/ Cations breakdown

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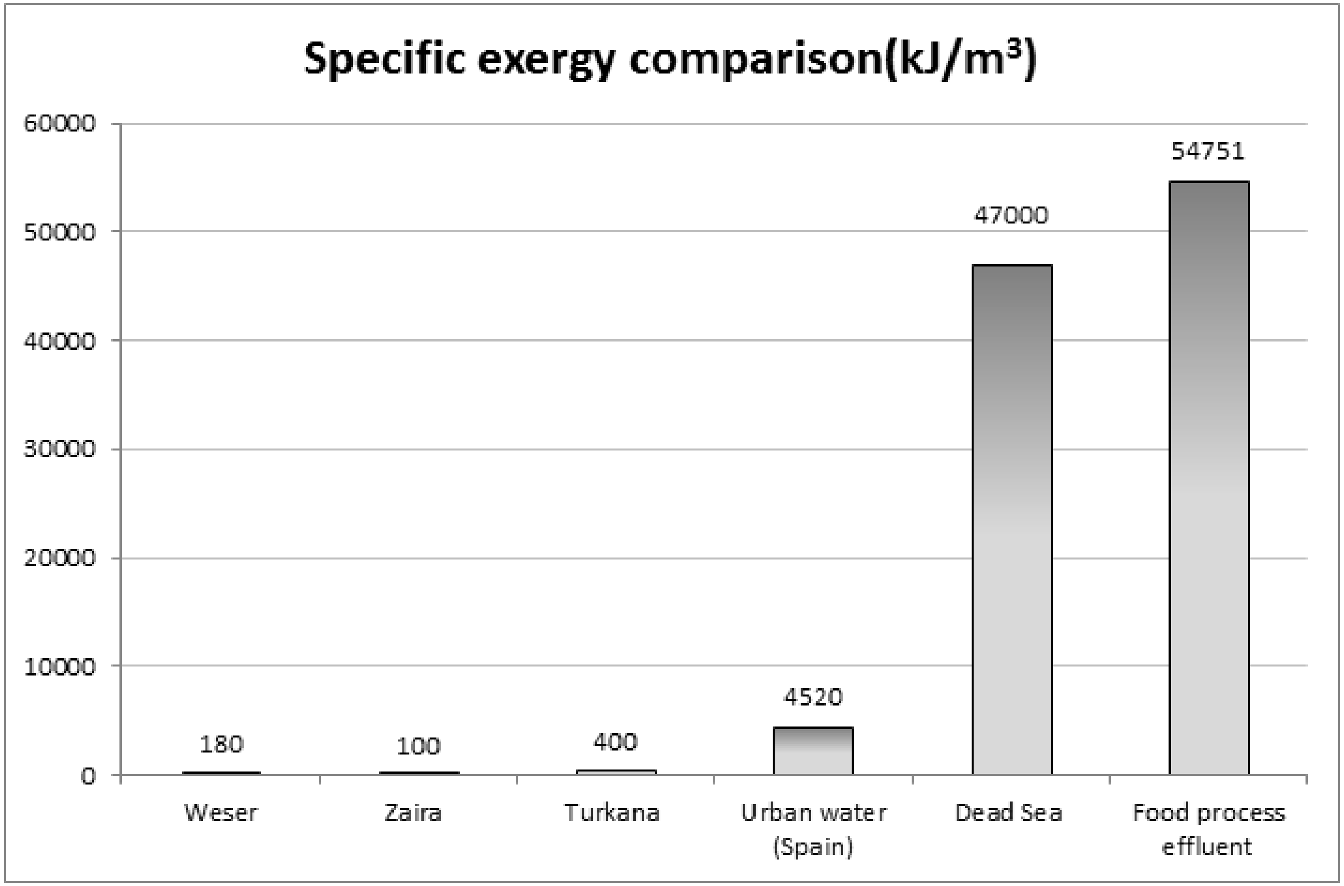
Comparison with water bodies around the world



After Chen et al., 2009

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Water treatment with high organic content (>500 mg O2/L)

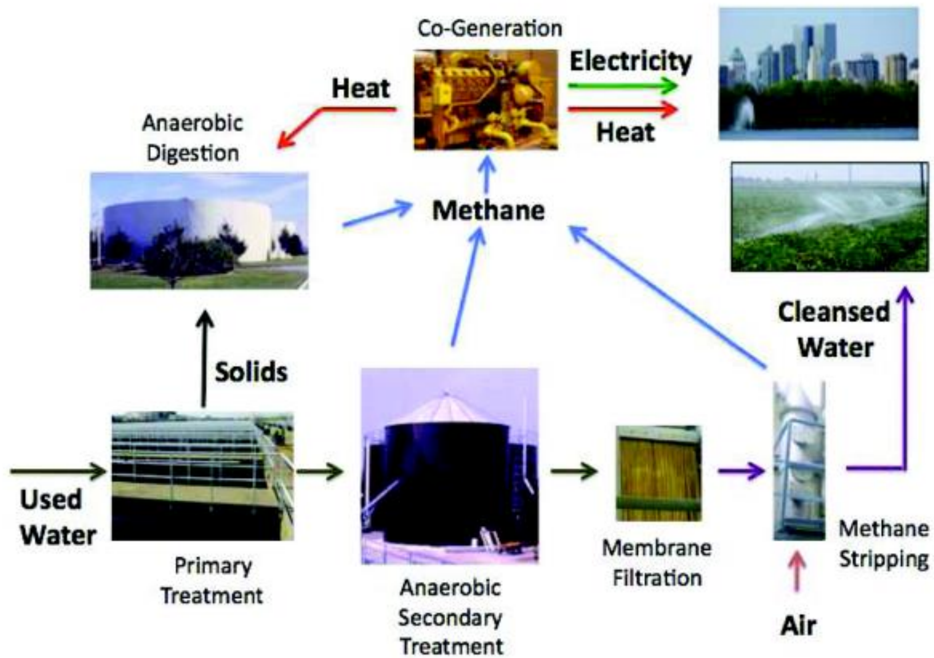

Figure 5 - A hypothetical wastewater treatment system (McCarty et al., 2011)

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Quantifying the saving in resources (results)

	Electricity	Nat. Gas exergy	Water	Total
	(MWh/week)	(MWh/week)	(MWh/week)	(MWh/week)
Option 1 (Baseline) – No treatment	204.4	212	40	457
Option 2 – anaerobic treatment	204.5	170	40	416
Reduction in resource use	-0.08 %	19.5 %	0%	9%

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Summary

- 9% savings estimated
- Resource use quantified in common units for a technology option
- Energy analysis overestimated the wasted thermal content of the effluent water.
  - It was 0.03% of the total exergy in the effluent(a lot of low grade waste heat).
- Additional knowledge and data requirements
- Results susceptible to method of calculation used.

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Technical Seminar Series

14th May
Resource Efficient Manufacturing: An Exergy Based Approach, Sanober Khattak, De Montfort

4th June
Sustainable value creation in manufacturing through maintenance services, Maria Holgado, Cambridge

All at 16:00-17:00

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