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No Compromise on Quality is Critical to Solid Recovered Fuel Production in Cyprus

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VASSILIKO CEMENT
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The Challenge

Meeting European Environmental Targets

- Waste Framework Directive Recycling Target
- Landfill Directive Biodegradable Waste Diversion Target
- Renewable Energy Directive Target

Identifying Cost Effective and Sustainable Solutions for Waste

- AD and composting options – poor residue quality issues
- Building a thermal treatment plant is a major barrier
- High quality and consistent fuels are required by industrial thermal processes like cement production

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The Opportunity

- Municipal Solid Waste is an indigenous fuel source to the island
- A major thermal conversion industry is available on the Island (Vassiliko Cement Works Ltd)
- Major investments in new advanced technologies and alternative fuel handling systems
- Significant fossil fuel substitution
- Significant demand for Solid Recovered Fuel (SRF) as an auxiliary fuel
- Rates of substitution increase with fuel quality
- 30-40% or higher substitution rates are possible
- Could represent a bulk market for 110,000 t SRF
- **Multi-criteria analysis consistently identifies MBT → SRF → cement industry as the most sustainable option for MSW management in Cyprus (Nikolaides *et al* 2016)**

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Advantages and Disadvantages of MBT → SRF

Advantages

- 100% participation rate
- Captures all recoverable value
- Established technologies
- Control over product outputs through advanced biodrying and separation technologies
- Minimises landfill disposal (a zero rate is achievable)
- Simple bin and collection systems
- Flexible and adaptive to future demands
- Does not compete with other recycling schemes

Disadvantages

- Mixed waste treatment favoured less than source separation
- Negative public perception towards waste processing facilities
- ***Markets and quality are critical for fuel and other outputs***

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Shanks MBT - Frog Island, East London, 180,000 t/y MSW

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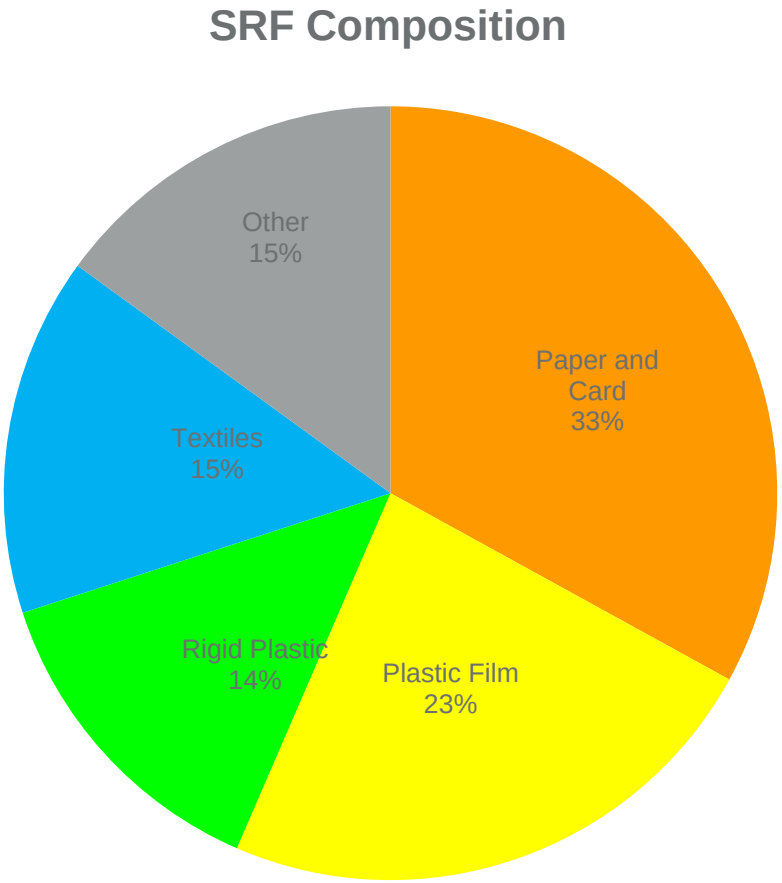
Average ELWA SRF Analysis



- Waste origin = 97% MSW, 3% commercial
- 85% of material = paper, card, plastics & textiles
- 'Other' = misc combustibles, ferrous & non-ferrous, putrescible
- Material shred size = 50mm (variable according to off-take market requirements)
- Particle Size <50mm = 98% (VCW PSD <35mm)
- Energy potential (CV) = 17.0MJ/kg (net CV) (VCW <16 MJ/kg)
- Moisture content = 16.9% (VCW <18%)
- Ash content = 7% (VCW <15%)
- Chlorine = 0.41% (VCW <0.8%)
- Delivery method = compacted & loose loaded on trailers for road haulage
- End use = pre-heating, cement kiln pre-calciner
- Production potential = 27.5% of input, by weight

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MBT Mass Balance

		Frog Island, Target		Jenkins Lane, June 2014		Cumbria 2014/15		Comment
Route	Outputs	**t**	%	t	%	t	%	
Diversion	SRF/RDF	115,679	64.3%	6,756	45.7%	55814	48.8%	Used as alternative fuel in cement production and in efw plant
Diversion	Moisture	52,380	29.1%	5,007	33.9%	31612	27.7%	Evaporative losses
Recycling	Mixed Metals	3,827	2.1%	283	1.9%	2622	2.3%	Recycled through the scrap metal industry
Recycling	Glass & Stone	1,776	1.0%	229	1.5%	8763	7.7%	Used as aggregate in road building
Recycling	Fines (0 - 6mm)	6,138	3.4%	91	0.6%	8518	7.5%	Goes for further treatment for land restoration
Landfill	Dust	200	0.1%	0	0.0%)			Extracted from refinement air treatment
Landfill	Fines (0 - 6mm)			548	3.7%	6882	6.0%	
Landfill	RDF			1,872	12.7%)			
	Total Input t	**179,800**	**100.0%**	**14,787**	**100.0%**	**114,211**	**100%**	
	Summary							
	Diversion		93.3%		79.6%		76.5%	
	Recycling		6.%		4.1%		17.5%	
	Landfill		0.10%		16.4%		6.0%	
	Total		100%		100%		100%	

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Rotary Biodrying Research with Vassiliko Cement Works, Cyprus

- Metabolic heat removes water from biodegradable waste
- Critical control of microbial activity at low moisture
- Optimised rotation, aeration and temperature management
- Minimises drying time: <3 days
- Small plant foot print, reduced capital and operating costs
- Maximises calorific value, fuel homogeneity and recyclate recovery
- Direct combustion or pretreatment in advanced thermal treatment (gasification)
- Local developed technology

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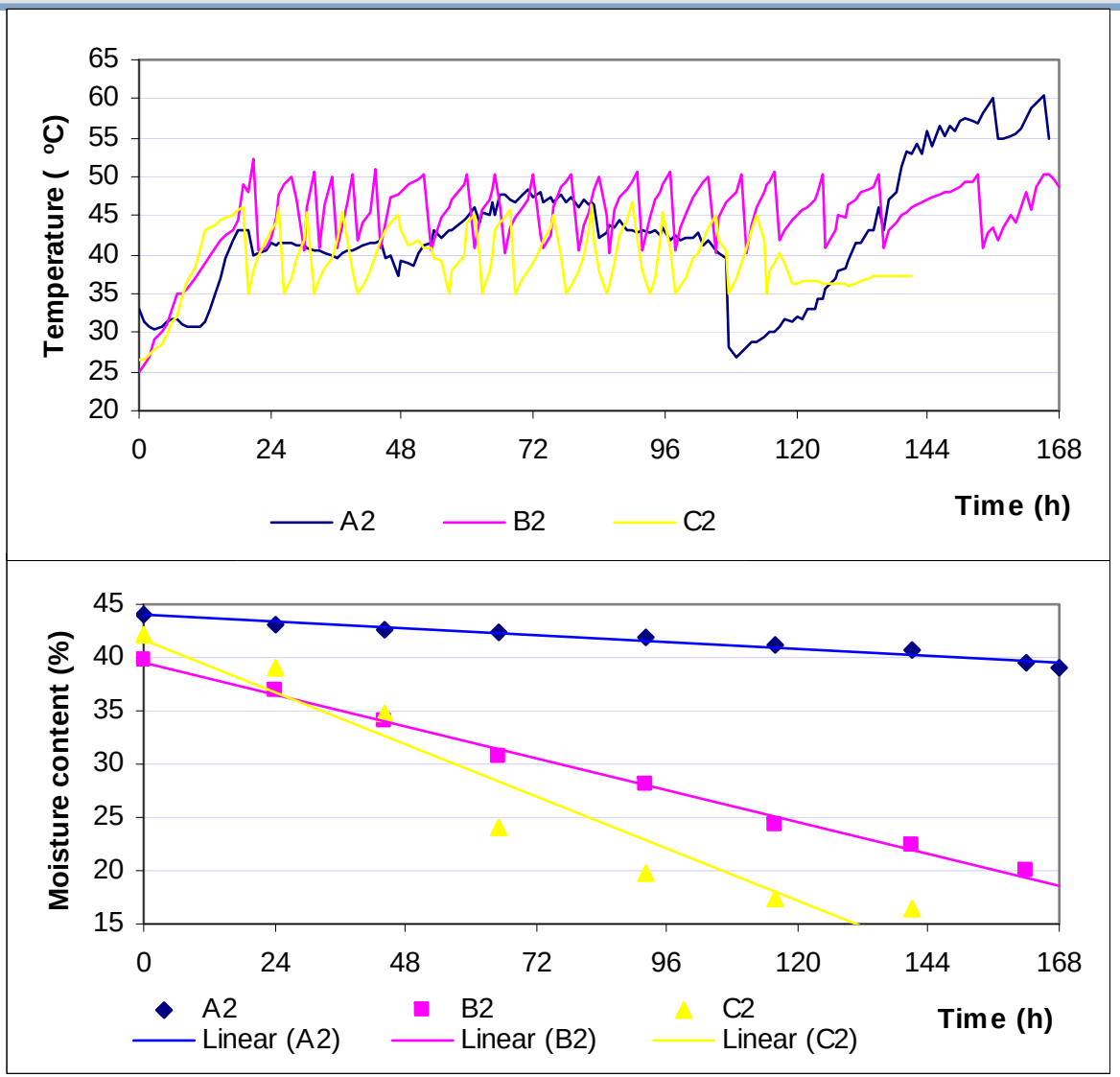
Rotary Biodrying Technology Can Reduce Processing Time to ≤3 Days and Increase Fuel Properties and Consistency



Vassiliko Cement Works at a Glance

- **Established in 1963**
  - First production in 1967
  - 2nd Lepol Kiln line in 1969
  - 3rd Lepol Kiln line in 1975
  - 4th Lepol Kiln line in 1985
  - New BAD 2-string 5 stage Pre-Calciner Kiln 2011
  - State of the art feeding system for alternative fuels 2014-2016

- **Cement Plant**
  - Location : Vassiliko, Cyprus
  - Raw materials : Main quarry 7 km from plant
  - Kiln capacity : 2 m tpa clinker – the biggest cement kiln in Europe
  - Grinding capacity : 2,4 m tpa cement
  - Other infrastructure : Vassiliko port

6000T/D Burning System Heat Balance

					kcal/kg	kJ/kg	
System Cap.:	6000 tpd						
	250000 kg/h-cl.						
R/C factor:	1.613 kg/kg						
	403193 kg/h-feed.						
H-consumption	709 kcal/kg-cl.						
Fuel HV.	8200 kcal/kg-fuel						
Kiln gas	0.40 Nm³/kg						
Kiln gas dust	0.15 kg/Nm³						
by pass	5%						
Heat in:							
Kiln feed	1.613 kg/kg	60 °C	0.207 kcal/°C-kg		20.03	83.86	2.7%
Fuel	0.086 kg/kg	8200 kcal/kg-cl.			709.00	2968.44	95.5%
Primary air	0.109 Nm³/kg	20 °C	0.311 kcal/°C-Nm		0.68	2.84	0.1%
Cooling air	2.000 Nm³/kg	20 °C	0.311 kcal/°C-Nm		12.42	52.01	1.7%
Total input					742.13	3107.15	100.0%
Heat out:					kcal/kg	kJ/kg	
Theoretical heat of clinker burning					402.15	1683.71	54.2%
Moisture evaporation	0.02 kg/kg	1.0 %	564 kcal/kg		9.10	38.09	1.2%
Preheater exhaust	1.32 Nm³/kg	301 °C	0.348 kcal/°C-Nm		137.64	579.27	18.5%
Entrained dust	0.08 kg/kg	301 °C	0.210 kcal/°C-kg		5.09	21.33	0.7%
Bypass gas	0.02 Nm³/kg	1050 °C	0.386 kcal/°C-Nm		8.13	34.06	1.1%
Bypass dust	0.00 kg/kg	1050 °C	0.257 kcal/°C-kg		0.81	3.40	0.1%
Cooler middle air	0.00 Nm³/kg	473 °C	0.323 kcal/°C-Nm		0.00	0.00	0.0%
Cooler exhust	1.15 Nm³/kg	227 °C	0.316 kcal/°C-Nm		82.31	344.61	11.1%
Clinker	1.00 kg	85.0 °C	0.192 kcal/°C-kg		15.45	64.69	2.1%
Radiation, Preheater+Calciner					22.45	93.99	3.0%
Kiln					31.40	131.47	4.2%
Cooler					4.15	17.37	0.6%
Tertiary air duct					6.28	26.27	0.8%
Other					17.17	71.88	2.3%
Total output					742.13	3107.14	100.0%

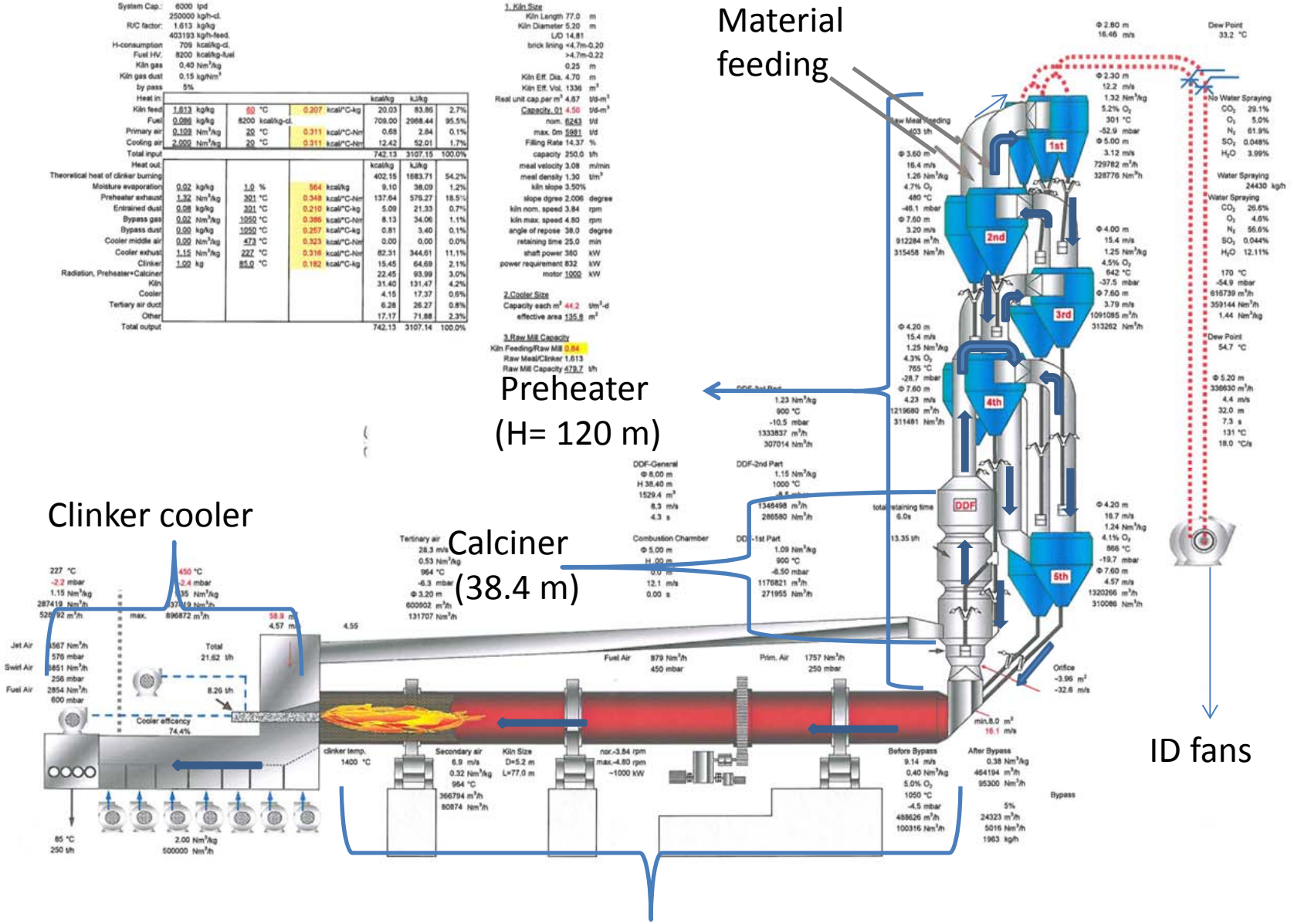
6000T/D Main Equip. Spec.

1. Kiln Size
- Kiln Length 77.0 m
- Kiln Diameter 5.20 m
- L/D 14.81
- brick lining <4.7m-0.20, >4.7m-0.22
- 0.25 m
- Kiln Eff. Dia. 4.70 m
- Kiln Eff. Vol. 1336 m³
- Real unit cap.per m³ 4.67 t/d-m³
- Capacity_01 4.50 t/d-m³
- nom. 6243 t/d
- max. 0m 5981 t/d
- Filling Rate 14.37 %
- capacity 250.0 t/h
- meal velocity 3.08 m/min
- meal density 1.30 t/m³
- kiln slope 3.50%
- slope dgree 2.006 degree
- kiln nom. speed 3.84 rpm
- kiln max. speed 4.80 rpm
- angle of repose 38.0 degree
- retaining time 25.0 min
- shaft power 380 kW
- power requirement 832 kW
- motor 1000 kW

2.Cooler Size
- Capacity each m² 44.2 t/m²-d
- effective area 135.8 m²

3.Raw Mill Capacity
- Kiln Feeding/Raw Mill 0.84
- Raw Meal/Clinker 1.613
- Raw Mill Capacity 479.7 t/h

6000T/D Preheater Figures

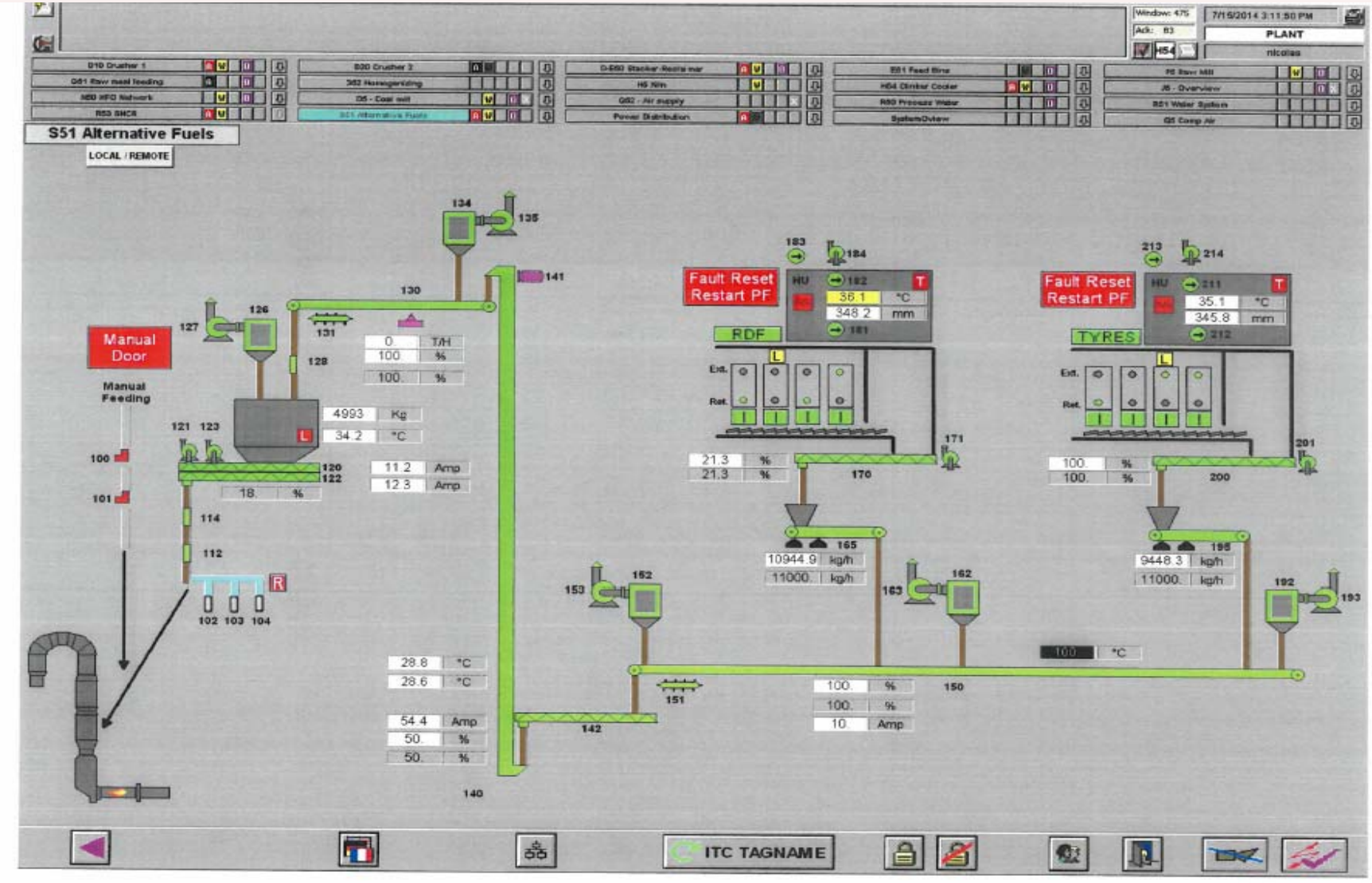


Push floor feeding bin for RDF

2.6 Photo –Chopped Tyres Push Floor Feeding Bin

Push floor feeding of chopped tyres to screw feed

Alternative fuel and raw material delivery and supply system



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Debaling and Drum screening for imported baled RDF/SRF

Tubular ‘pipe’ belt conveyor transporting from Debaler over to Feed Bins

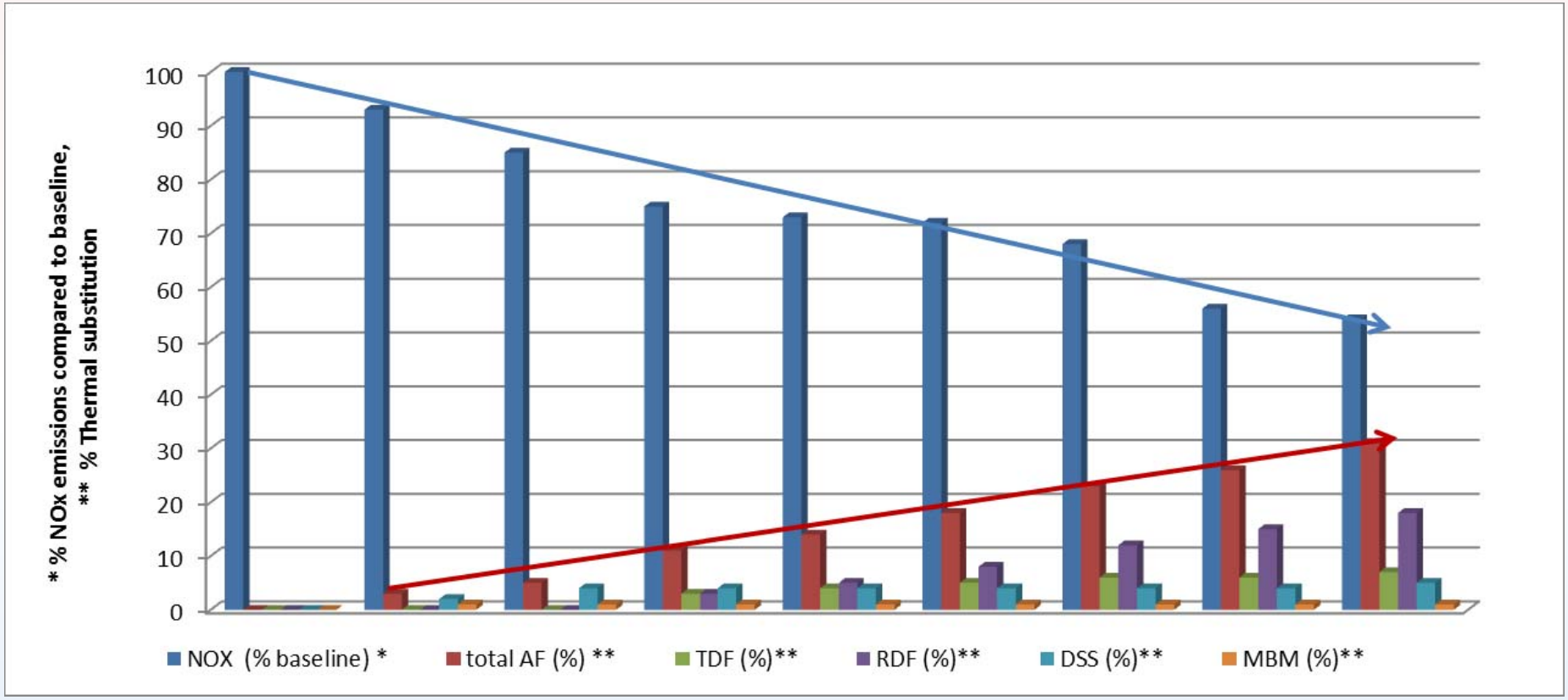
Important quality criteria for SRF used in cement kilns

- Cl content: Cl can cause build up formation in static combustion chambers (calciner) restricting gassflow.
- Ash content: ash is incorporated in the product of the kiln as raw material. Clinker reactivity can be affected.
- Moisture content: Causes expansion in cement kiln gasses and increased power consumption. It also affects the combustion profile and transport of the material to the kiln.
- Particle size: the smallest the better. Combustion of coarse material is slow and the retention time in the calciner may not be adequate for complete combustion.
- NOx emissions increase with increasing particle size and moisture of SRF.
- Calorific value: Always related to Cl content and ash content. Using SRF with high calorific value reduces Cl and ash input for a specific thermal substitution.
- Homogeneity: The most important parameter for smooth kiln operation. Variable moisture, calorific value, particle size etc cause fluctuations in cement kiln temperatures with detrimental effects on product quality.

SRF utilization at Vassiliko Cement Works

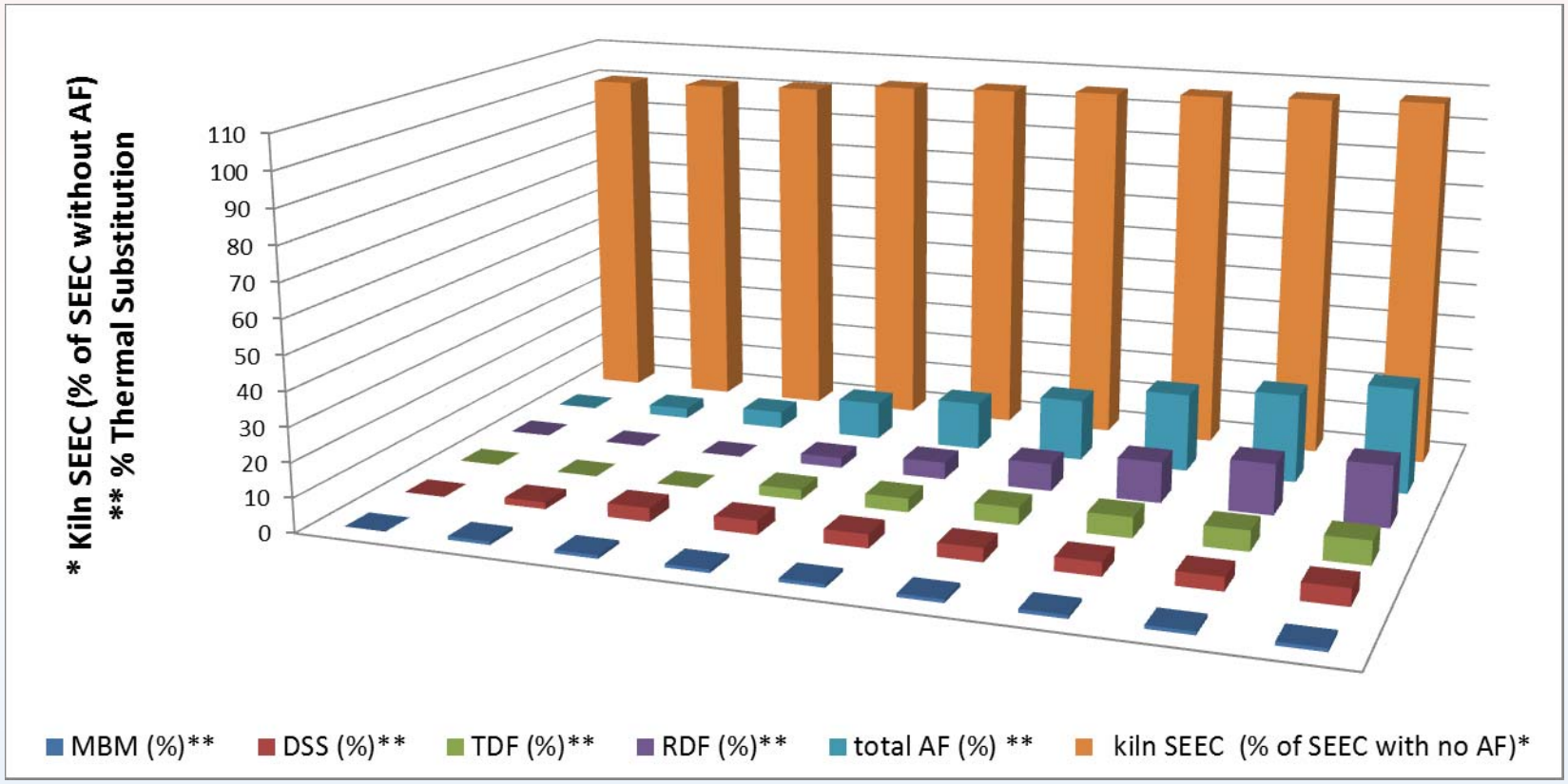
- Test with compost like output (CLO) from Larnaka MBT plant were performed on 2014-2015.
- CLO was fed to the calciner for a period of 6 months
- Thermal substitution of 5 % was hardly reached with more than 100 tns utilized on a daily basis. There was negative impact on clinker quality and process performance.
- Since 2015, high quality SRF is imported from abroad.
- Currently, more than 300 tns of SRF is utilized on a daily basis equivalent to approximately 30 % thermal substitution.
- Successful tests has been carried out with more than 400 tns of SRF fed to the kiln on a daily basis.

Effect of AF utilization on NOx baseline emissions



DSS- MBM co-ground, TDF-RDF pre-blended

Effect of AF utilization on Specific Electrical Energy Consumption (SEEC)



DSS- MBM co-ground, TDF-RDF pre-blended

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Conclusions

- High diversion and recovery rates can be achieved close to 100%
- Captures all the residual value in waste
- Compatible with recycling systems
- A significant and committed end user is available for fuel products in Cyprus
- Critical fuel production processes and quality control to a specification (moisture, chemical composition) are necessary and achievable
- The technology combination is a great opportunity for Cyprus and would be a major lost opportunity if not taken forward