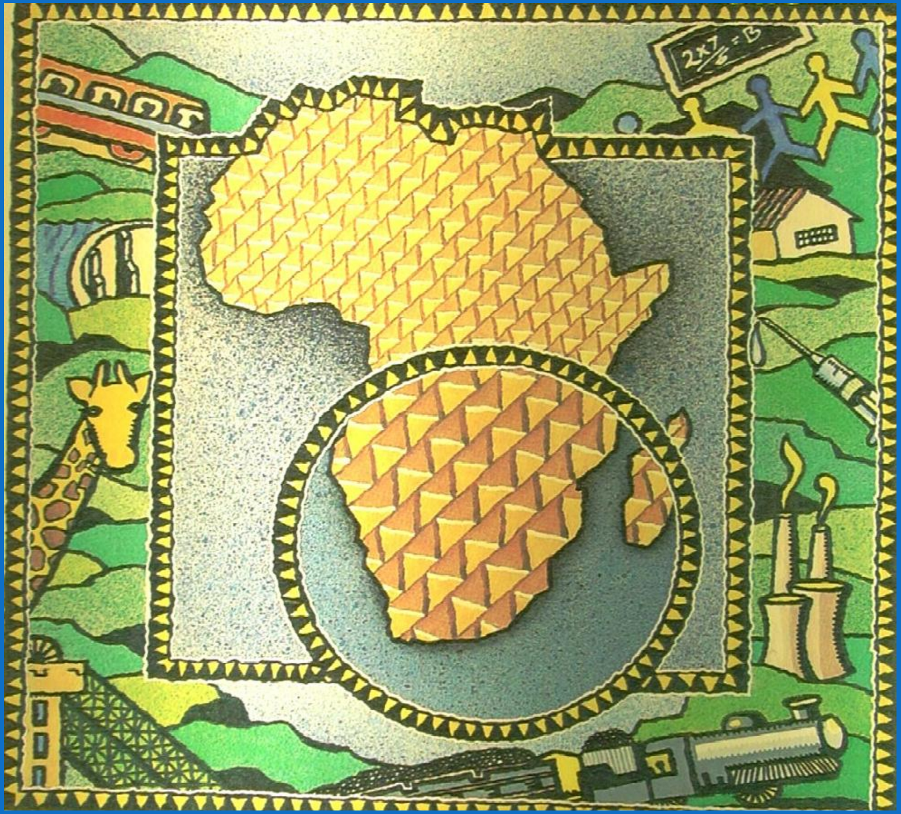
IMPACT of COAL QUALITY on COMBUSTION and POWER GENERATION

Southern African Scenarios and challenges in Clean Coal Technologies



Rosemary Falcon , Roland Zepeck, Mike Andrews

Powergen, Johannesburg November 2012

Outline

1. **Introduction -**low carbon economy, dependence, prod users, qualities
2. **Current experiences in combustion performance**
3. **Advanced Methods of Investigation**
    - Coal Quality Assessments
    - Temperature Assessments using Thermography
    - Observations
4. **Conclusions**

1. Introduction

- **Relevance of coal in SA -**
  - Highest dependence on coal in the world
    - 92% of energy /electricity is coal-based,
      - 14 major coal-fired power stations
      - 6 000 industrial boiler users
    - 40% of liquid fuels derived from CTL
    - Major foreign exchange earnings
- **Commitment to a Low Carbon Economy -**
  - South Africa is committed to GHG and CO_2 reduction
- **Methods to reduce GHG emissions**
  - CCS; Increased combustion and boiler efficiency

Future Technologies for a Low Carbon Economy

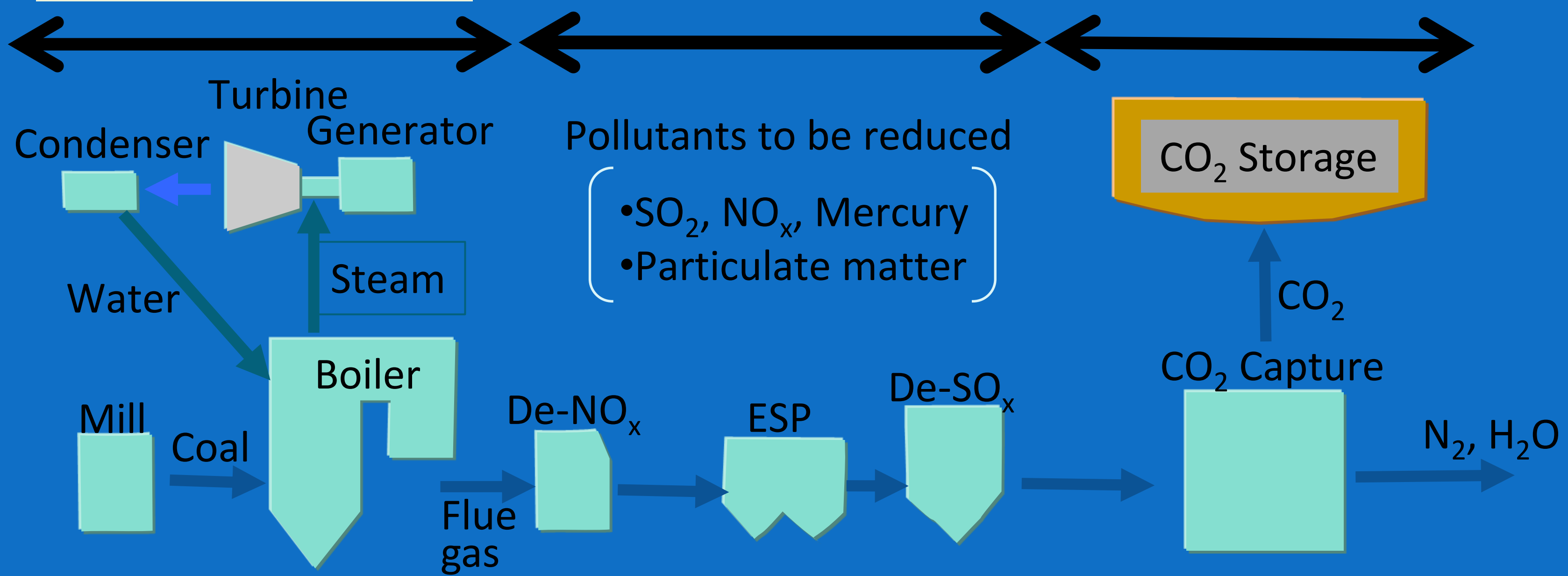
i.e. Reduction in both GHG and non-GHG (NO_x, SO_2, PM) emissions.

Technologies for cleaner coal generation

(1) Reducing coal consumption
(increase boiler efficiency)

(2) Reducing of non-GHG emissions

(3) Carbon Capture and Storage



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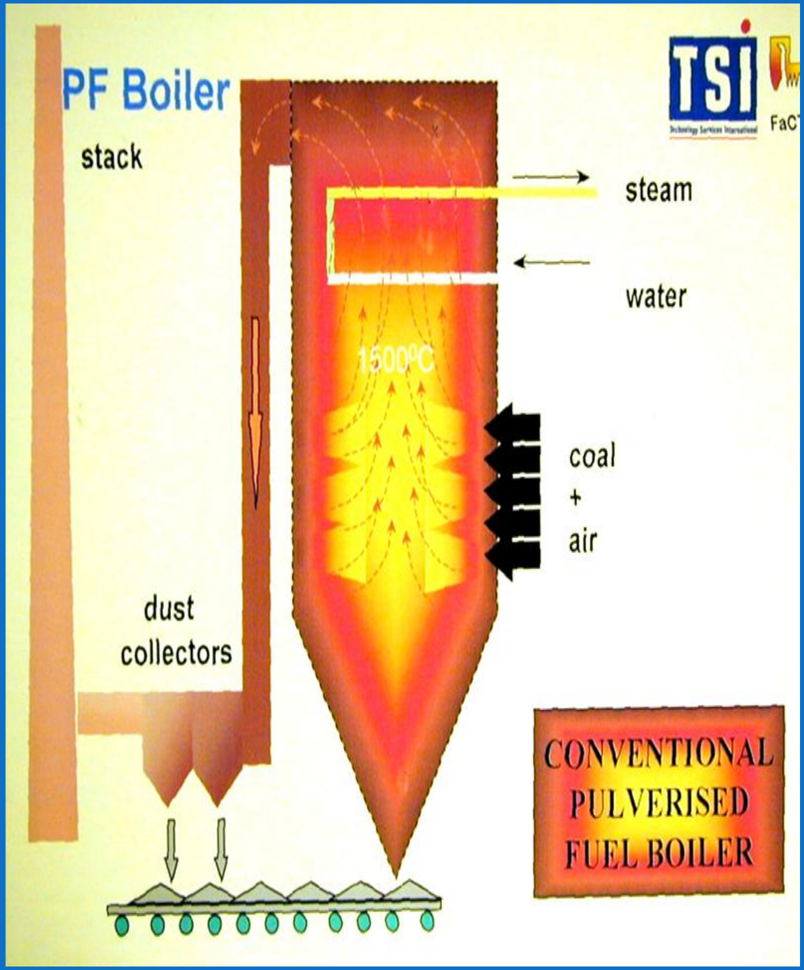
Challenges in the Coal Industry - 1

- **Run-of-mine coal qualities** are generally poor (high ash)
- **Beneficiation** of coal is a "must" (difficult)
- **Bulk of the best quality coals** have been mined out in conventional areas
- **Remaining coal resources** lie in relatively remote coalfields
- **Infrastructure** in those areas is as yet lacking (also many are difficult to mine conventionally)

Challenges in the Coal Industry - 2

- **Increasing export tonnages to the India and the Far East** leaves poorer grades for local markets
- **Increased costs** to obtain higher grades and qualities of coal
- **Variable combustion efficiencies** occur due to poor and variable feedstocks
- **Environmental constraints** increasingly stringent post 2012 (SO_x, NO_x, CO_2, particulates); C tax pending

LARGE SCALE POWER GENERATING PULVERISED FUEL BOILER



Power Station L –

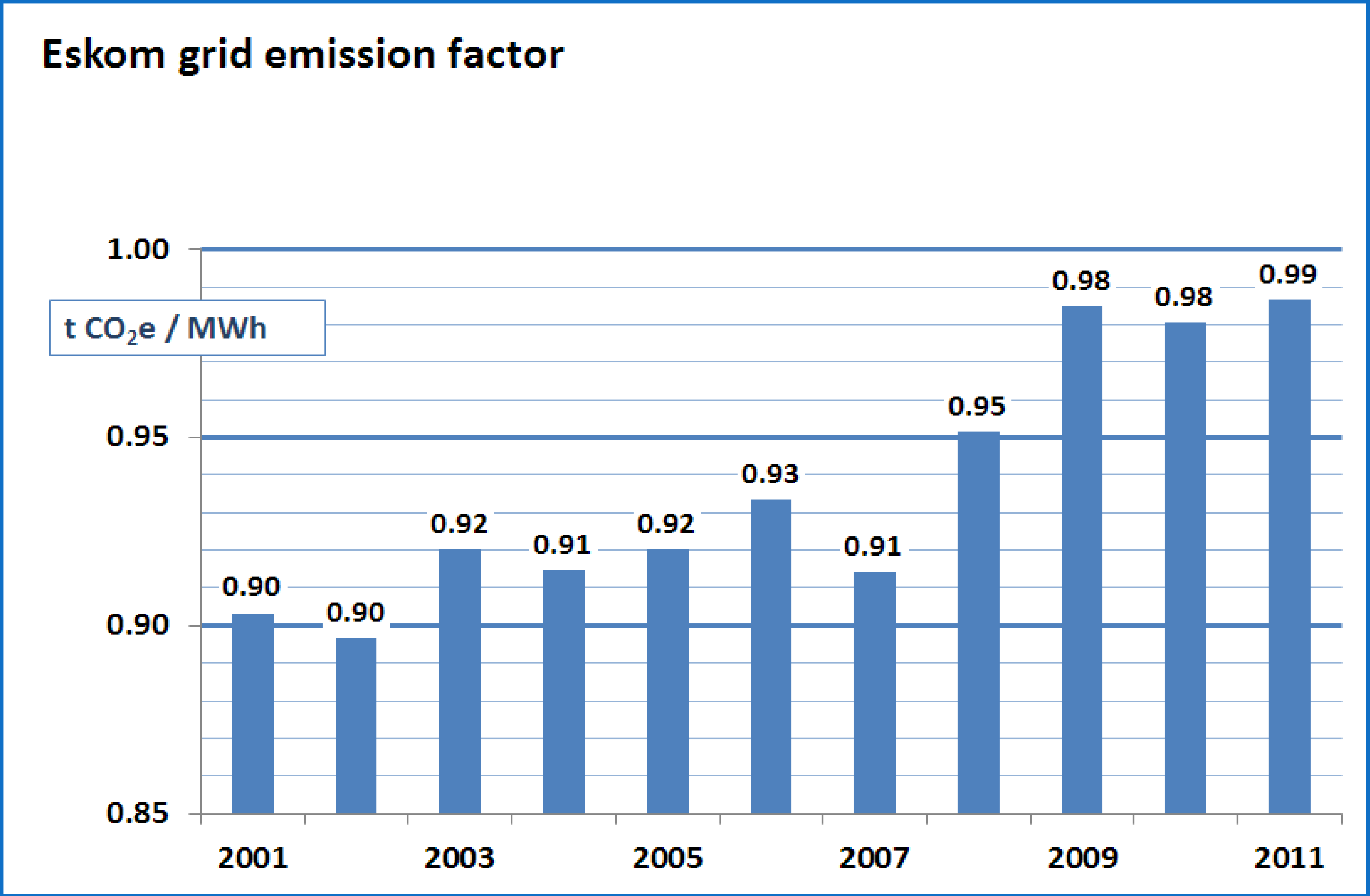
- Extreme difficulty in ignition
- Required 7 burner designs (Mark 7)
- 10m added to height of boiler
- 1m extra between rows of burners
- Tube mills selected to ensure extra fine pf sizes
- Burner mouths melted
- Pop-corn fly ash blocked air heaters
- Unusually high % of fly ash

Power Station M –

- Ignition and combustion difficulties when using coal from different zones in the coal sequence (non-design coals)

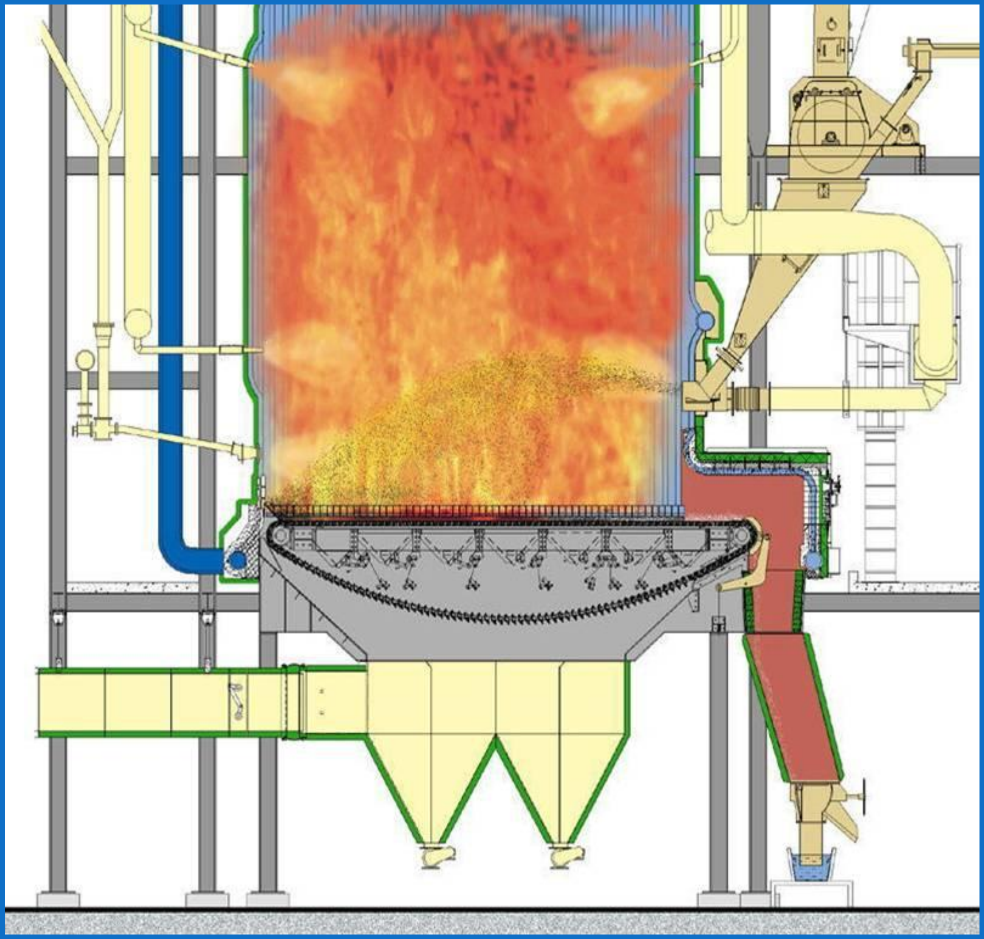
Unscheduled outages sometimes occur at a rate of one a week per boiler in some power stations

RISE IN CO_2 IN ESKOM OVER 10 YEARS



Eskom 2012

WATERTUBE BOILERS
CHAIN GRATE SPREADER STOKERS

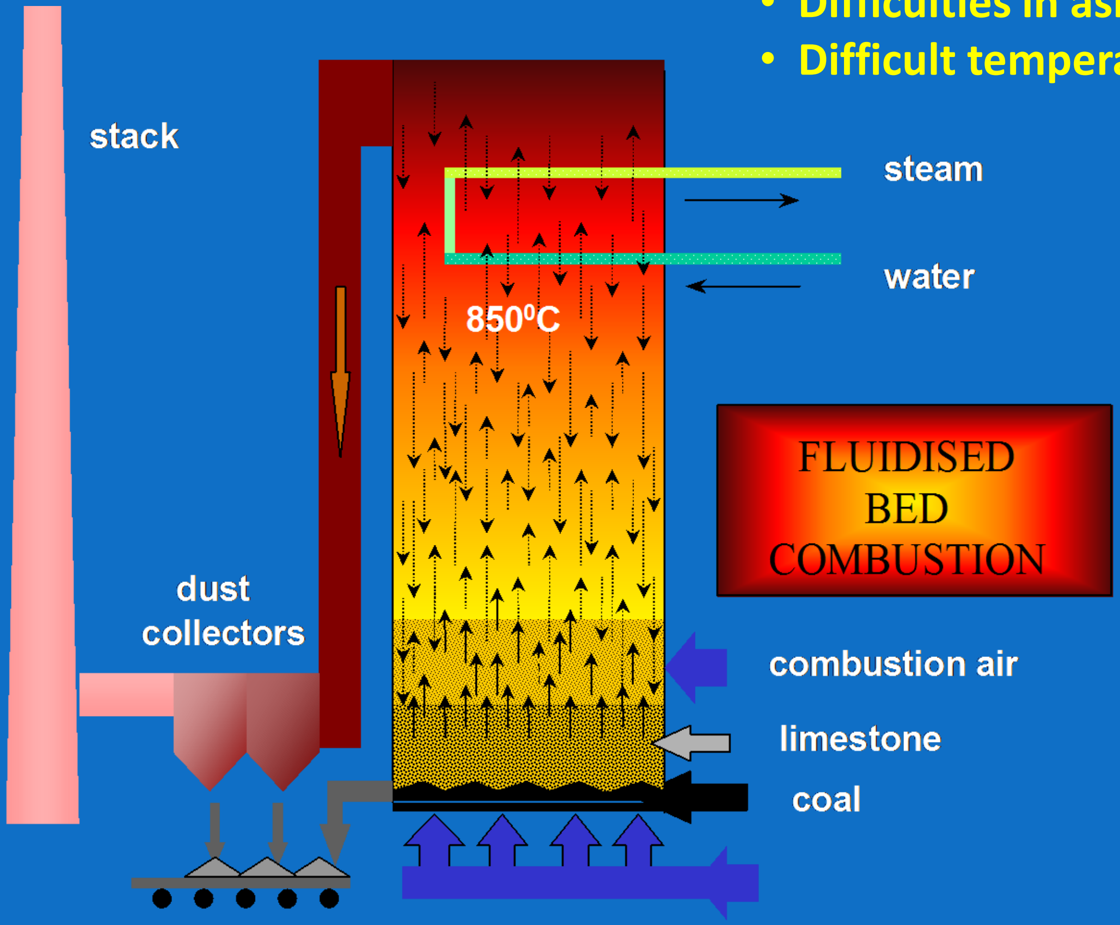


Spreader stoker Boilers:-

- Poor ignition when air-born
- Delayed combustion
- High level freeboard fire-ball
- Extreme slagging and fouling
- High percentage fines carryover
- Excessively high back end temperatures
- Excessively high temperatures on the grate, melting and fusing of chains and refractory linings

FLUIDISED BED BOILERS

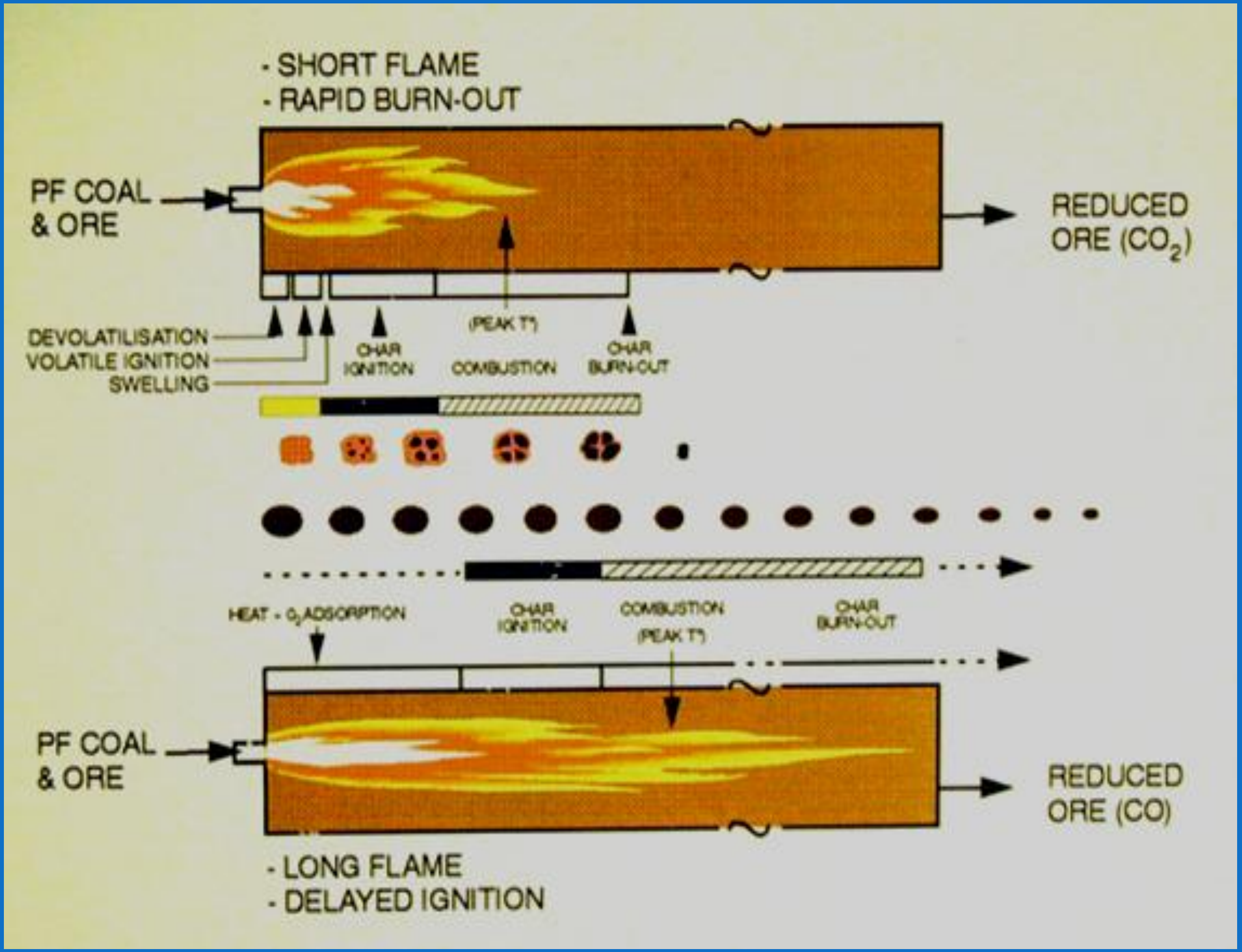
- Corrosion of the sparge pipes below the rims
- Agglomeration of particles within the moving bed
- Ash deposits dropping down to the base
- Difficulties in ash removal
- Difficult temperature control



During the commissioning of one bubbling bed boiler, the entire bed slagged

CEMENT KILNS

Flame configuration, heat transfer and burnout change with coal type - Grade, CV and proximate analyses are the same



Desired effect – short hot flame

Problem effect – long flame

SPECIFICATIONS OF TWO COALS

NB: THE SAME PROXIMATE ANALYSES BUT DIFFERENT COMBUSTION PROPERTIES

	Coal A	Coal B
Gross Calorific Value MJ/kg ad :	**28,70**	**28,93**
Proximate Analyses %ad :		
Inherent Moisture	3,7	2,4
Volatile Matter %ad	30,5	28,9
Ash Content %ad	11,1	12,2
Fixed carbon	54,7	56,5
Combustion efficiency	**83,0**	**66,0**
C in ash%	**4,4**	**15,5**

Slagging can occur even when ash fusion temperatures are high

Unburnt C in ash can be as high as 73% in some industrial boilers ; often 25-35%+

- It has therefore become vital to find ways to:-
  - increase combustion efficiency
  - Increase power generating capacity
  - Reduce outages (due to slagging, fouling, water tube/wall damage etc)
  - Minimise GHG and especially CO_2 emissions

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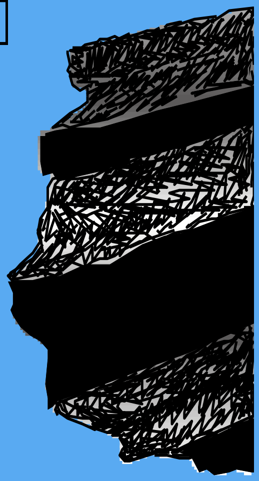
COAL QUALITY ASSESSMENTS FOR COMBUSTION

EMPIRICAL PROPERTIES

Chemical and Physical Analyses

OTHER	ASH	ULTM	PROXIM.
CV	SiO_2	C	H_2O
AFT	Al_2O_3	H	VM
SI	Fe_2O_3	O	ASH
HGI	CaO	N	FC
	MgO	P	
		S	



Conventional analyses

COAL QUALITY ASSESSMENTS FOR COMBUSTION

QUALITY OF FEEDSTOCK

EMPIRICAL PROPERTIES

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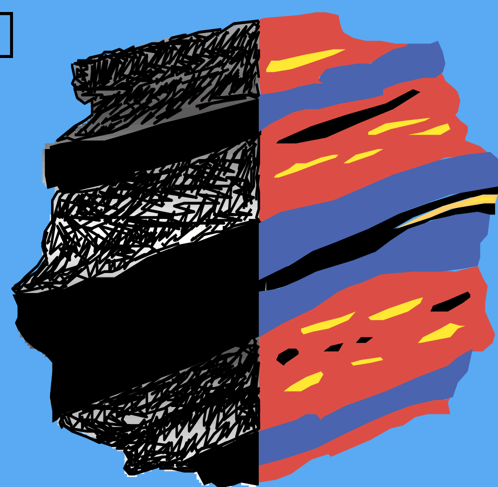
Conventional analyses



FUNDAMENTAL CONSTITUTION

Petrographic and CCSEM Analyses

ORGANIC	INORGANIC	RANK
MACERALS	MINERALS	MATURITY
Vitrinite	Quartz	Refl. of Vitrinite
Exinite	Clay	Std Deviation
Inertinite	Pyrite	Reflectogram

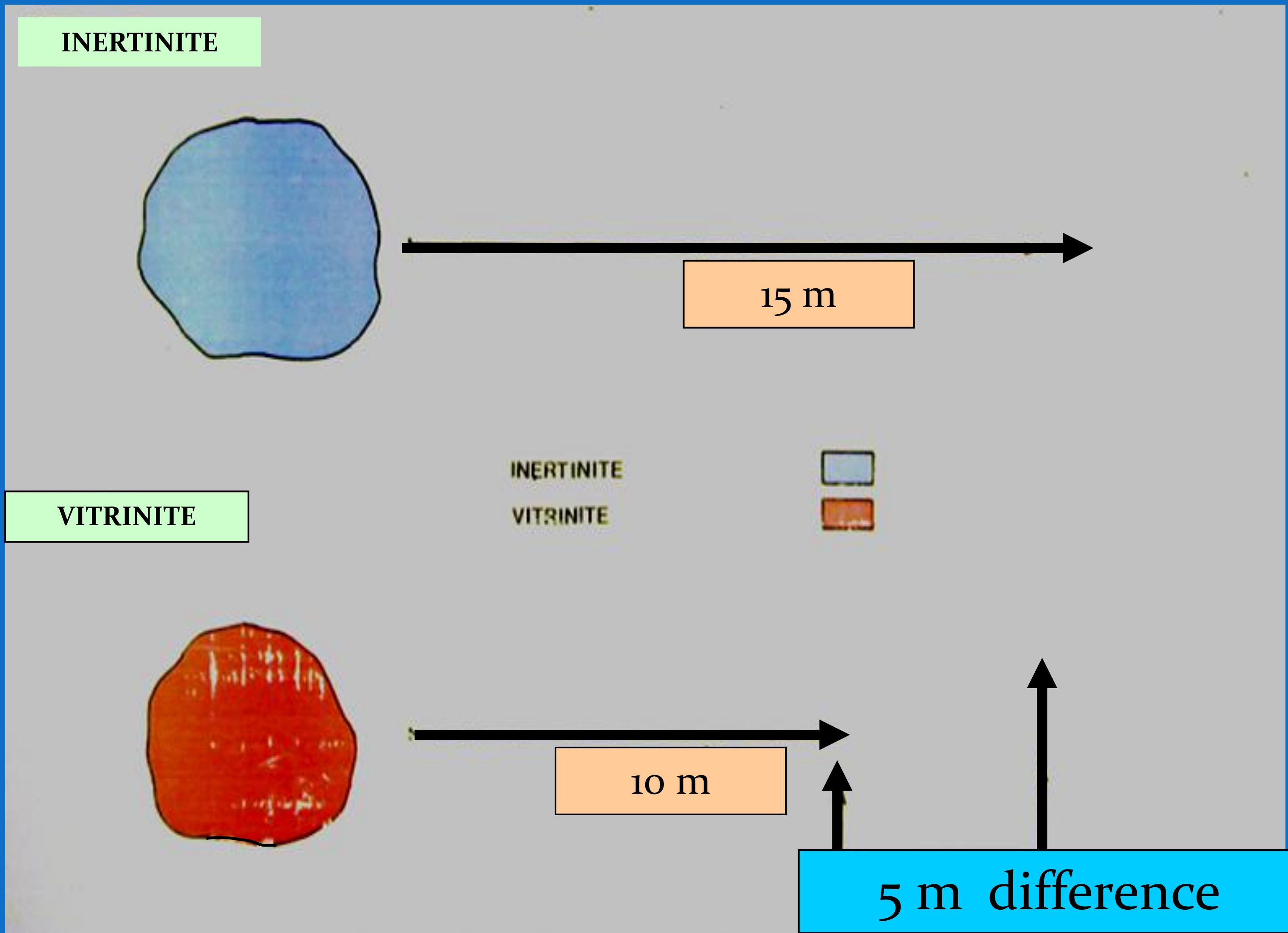
Additional analyses

KEY TO ORGANIC COMPOSITION IN COAL

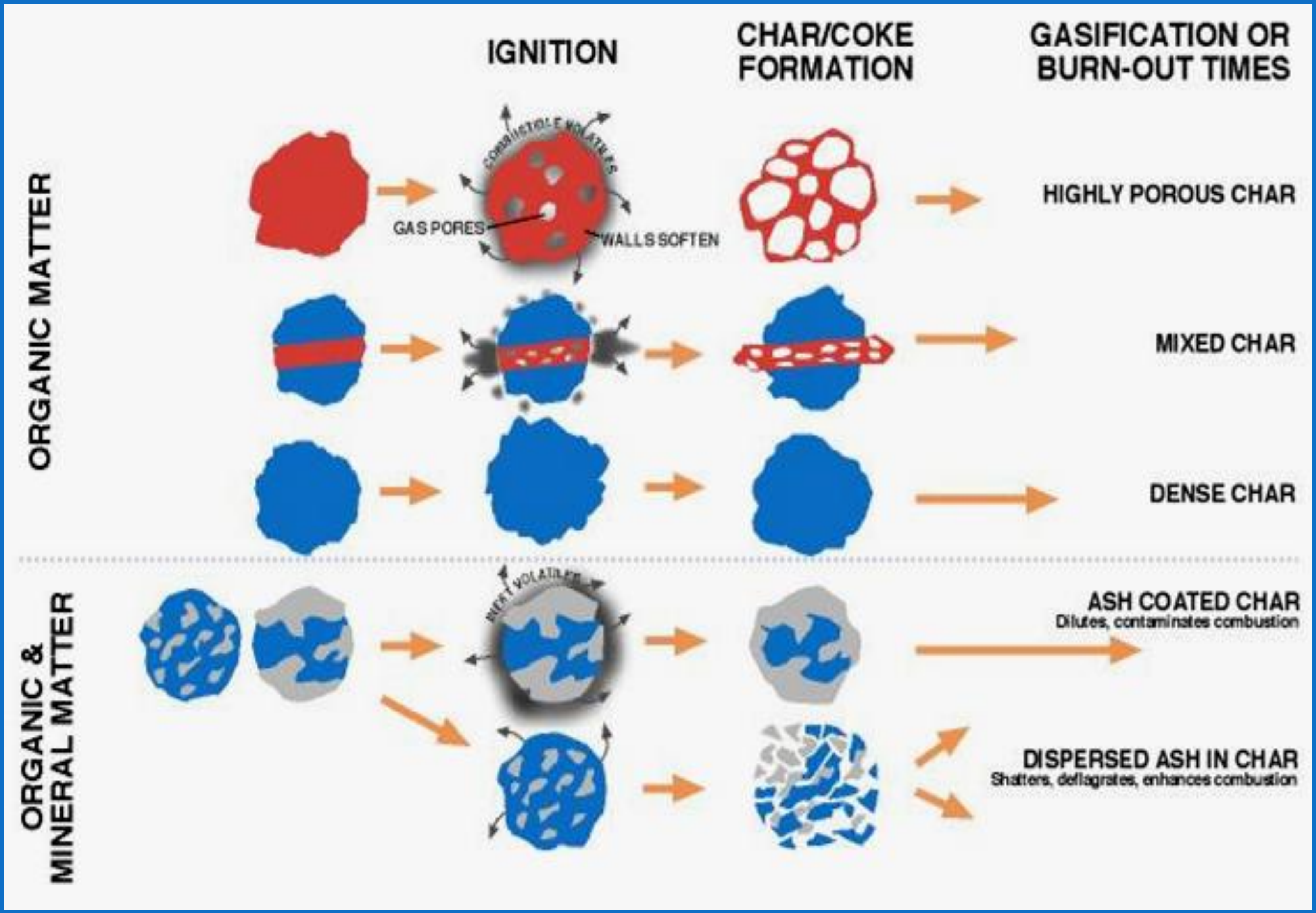
MACERALS – Microscopic residues of decomposed plants materials

RANK – Levels of maturity

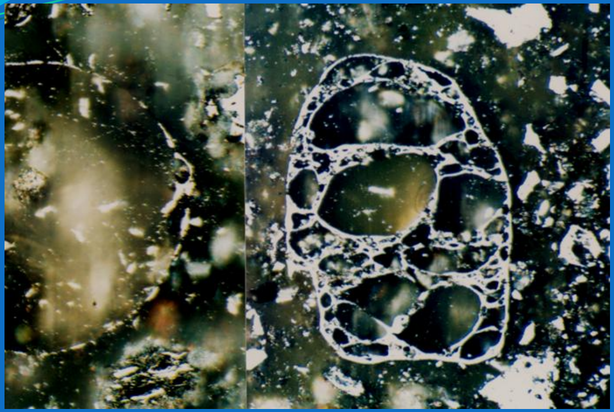
MACERAL BURNOUT TIMES AT 1 000ºC AND A VELOCITY OF 11m/sec



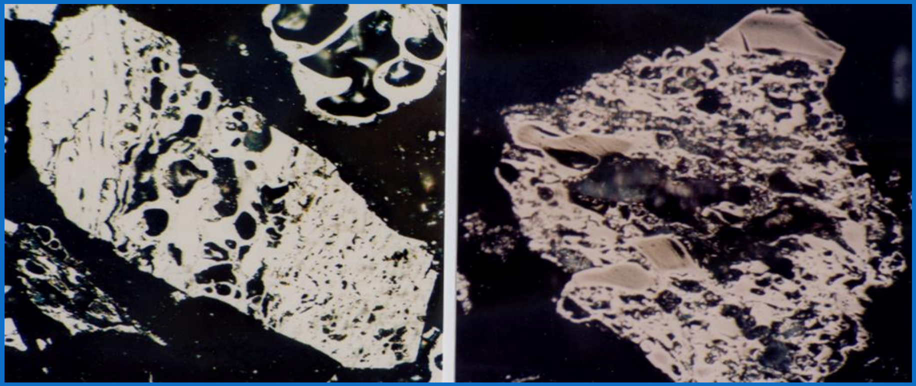
BEHAVIOUR OF COAL LUMPS ON HEATING
- BITUMINOUS COAL -



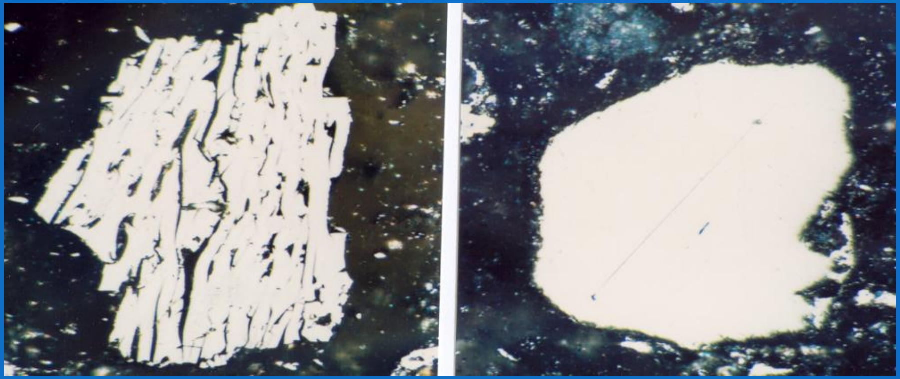
DOMINANT FORMS OF CHAR DERIVED FROM BITUMINOUS COAL



HIGHLY POROUS AND REACTIVE



MIXED SEMI-POROUS AND DENSE INERT

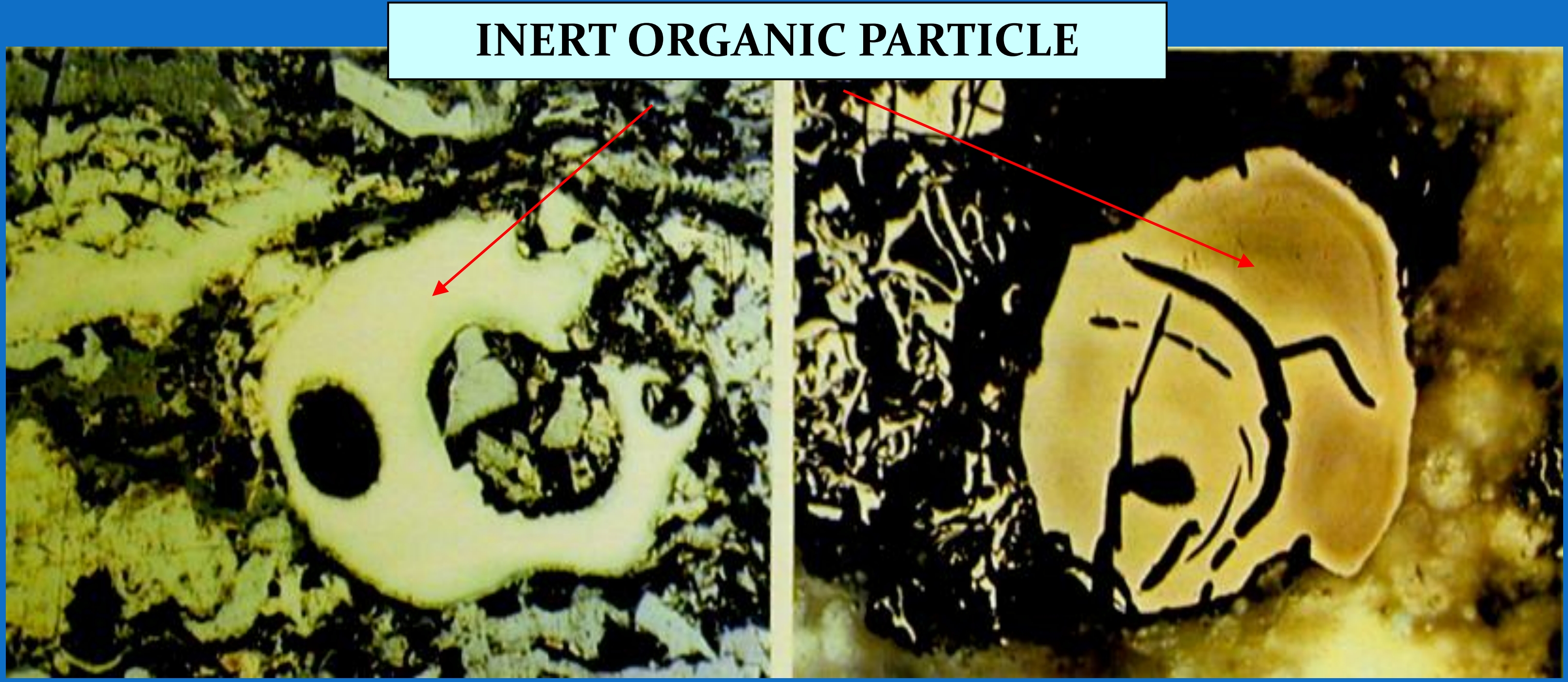


DENSE INERT

NON- REACTIVE

Power station L

<u>Coal particle</u> (feed) and <u>Unburnt char particle</u> (in fly ash)
NB: inert carbon form in char is unchanged
[T^{o}C in Boiler estimated to be 1800^{o}C]



Coal feedstock

Fly ash char

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Fixed carbon	54,7	56,5
Combustion efficiency	83,0	66,0
C in ash%	4,4	15,5
Petrographic Composition % :		
Maceral comp (vitrinite%)	62,0	30,0
Rank (RoV random%)	0,73	0,75

ORGANIC MATTER VARIES ACCORDING TO

Age, Continents and Regions (Gondwana to Laurasia)

Nature of the coal seam

Mine plan and extraction procedures

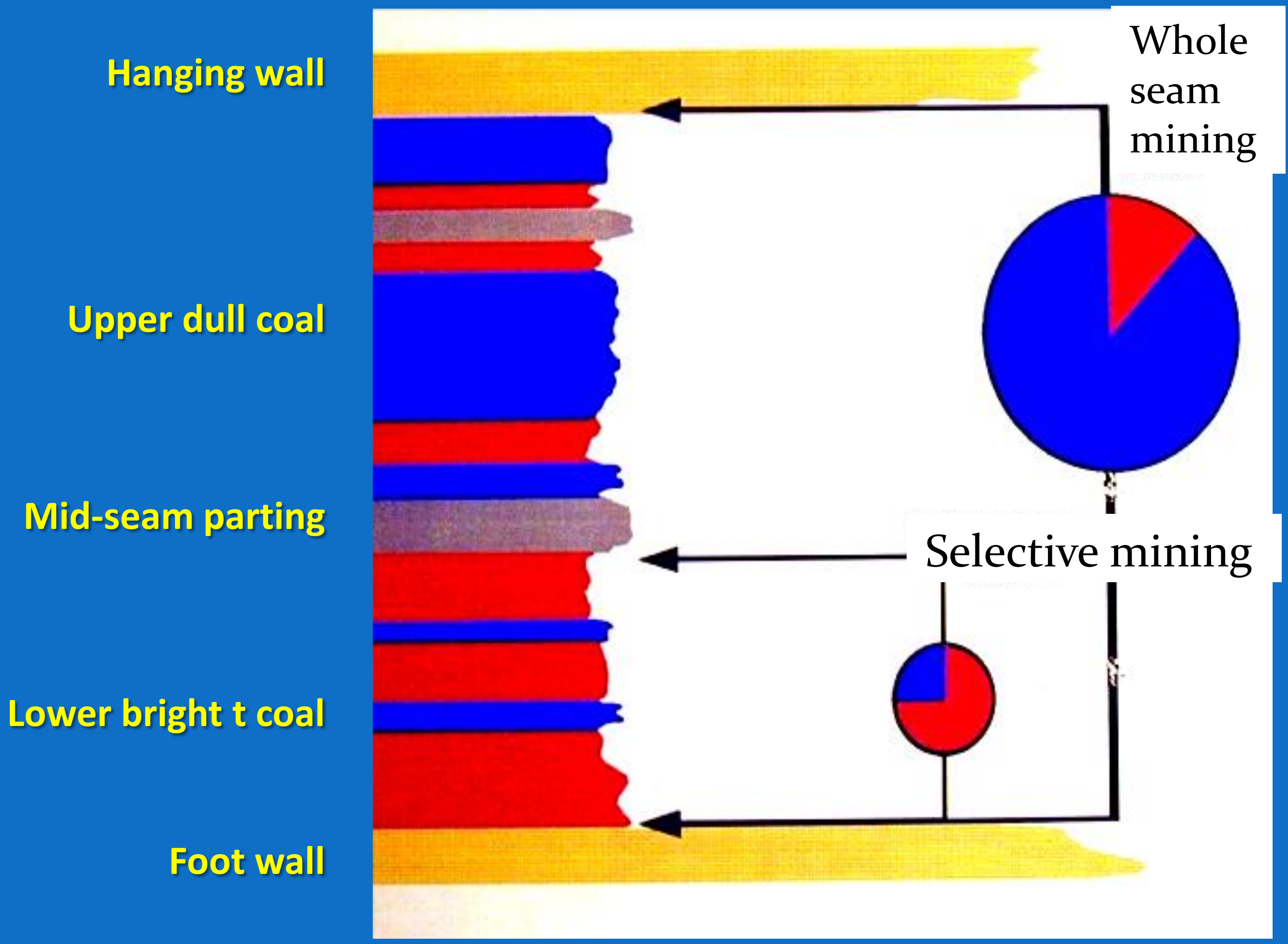
Levels of Beneficiation

Qualitative Organic Matter differences between Carboniferous Laurasian and Permian Gondwana Coals

	Key Technological Property on heating	GERMAN COAL RUN-OF-MINE	SOUTHERN AFRICAN RUN-OF-MINE
Organic % Petrographic components	Reactive vitrinite	80	25
	Highly reactive Liptinite/exinite	10	5
	Inert to semi-inert Inertinite	10	70
Ash %		Low	High

- * Petrographic observations indicate that reactive macerals ignite and burn out fast whereas inert maceral forms undergo delayed ignition and combustion.
- *

COAL QUALITY CHANGES SUBJECT TO MINE PLAN
- WHOLE SEAM OR SELECTED PARTS OF THE SEAM -

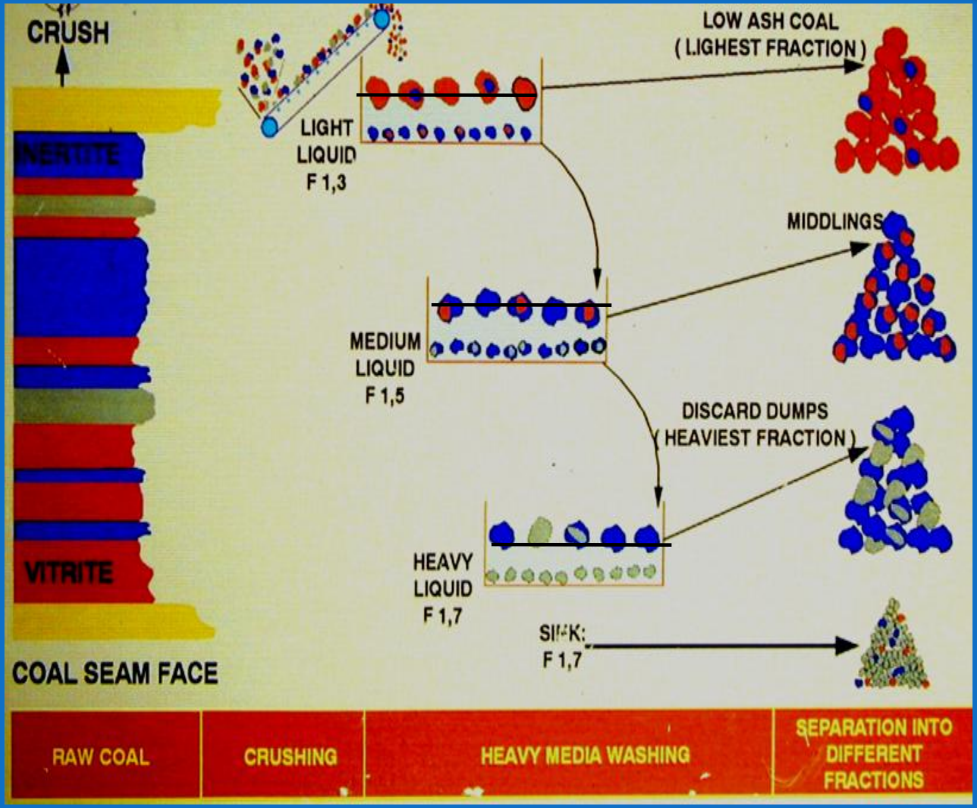


Dull coal is **inertinite** rich and poorly reactive

Bright coal is vitrinite rich and highly reactive

ASH, VOLATILE MATTER AND MACERAL CONTENT CHANGES WITH BENEFICIATION

HMS BENEFICIATION PROCESS



PRODUCTS		ASH %	VOLATILE%
Low ash	-	8	30
Middlings 1	-	14	24
Middlings 2	-	25	18
Discard	-	75	10

Facts and Fantasies

FANTASY	FACT
CV, proximate, ultimate and ash analyses are sufficient to market and select a coal	NO – coals from different geographic regions, collieries, seams, washed products will require **in-depth analysis and technical assessment** to ensure efficient combustion performance
All volatiles are combustible	NO – some are **incombustible and inert**; this is evident especially in coals with ash contents >20%; e.g. CO_2 from carbonate minerals and H_2O from clays
Low volatile coal is not likely to ignite and combust	NO – there are certain coals with low volatiles which **will ignite and combust if the combustion conditions are suitable** – BUT IT IS NECESSARY TO COMPENSATE FOR THE MORE EXTREME CONDITIONS NECESSARY TO BURN THEM

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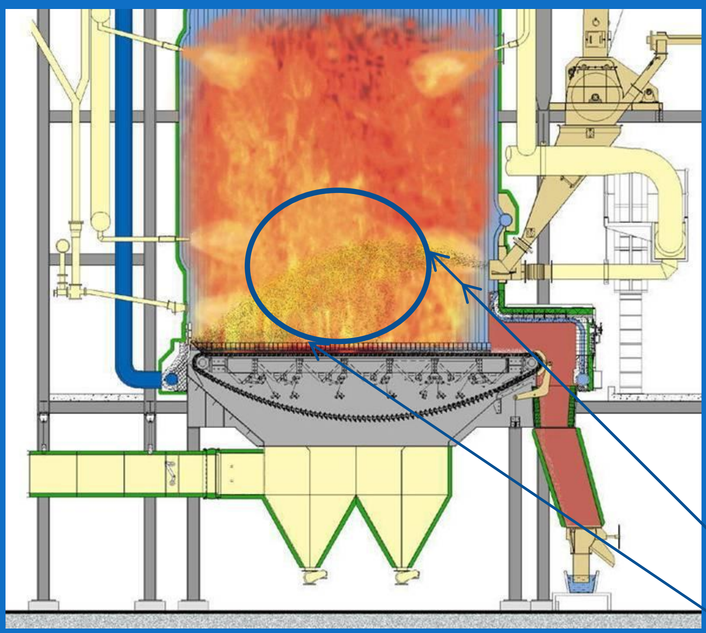
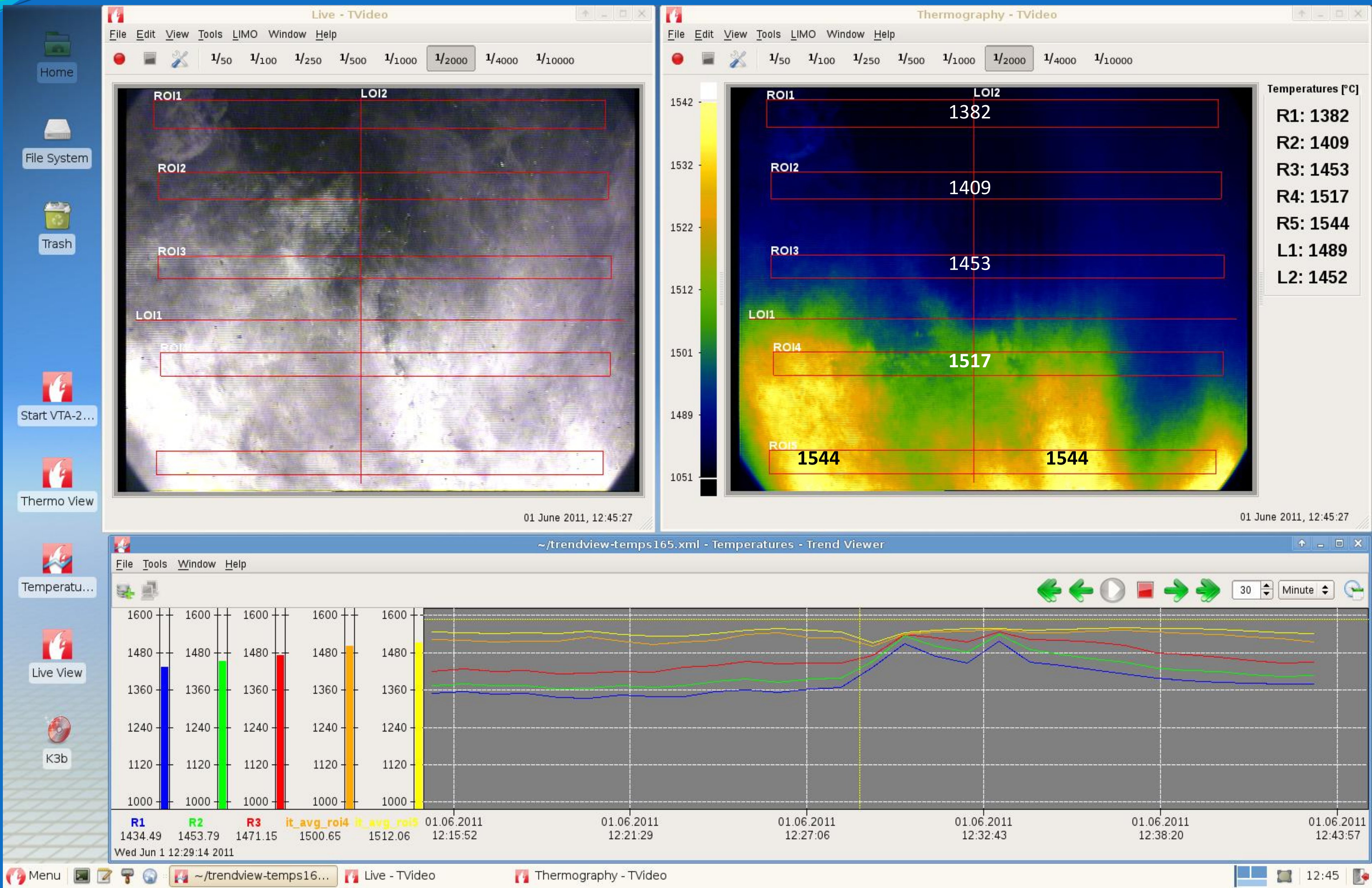
Video – Grate-fired furnace



Lateral view of thermal camera into grate-fired boiler – computer determines temperature based upon colour

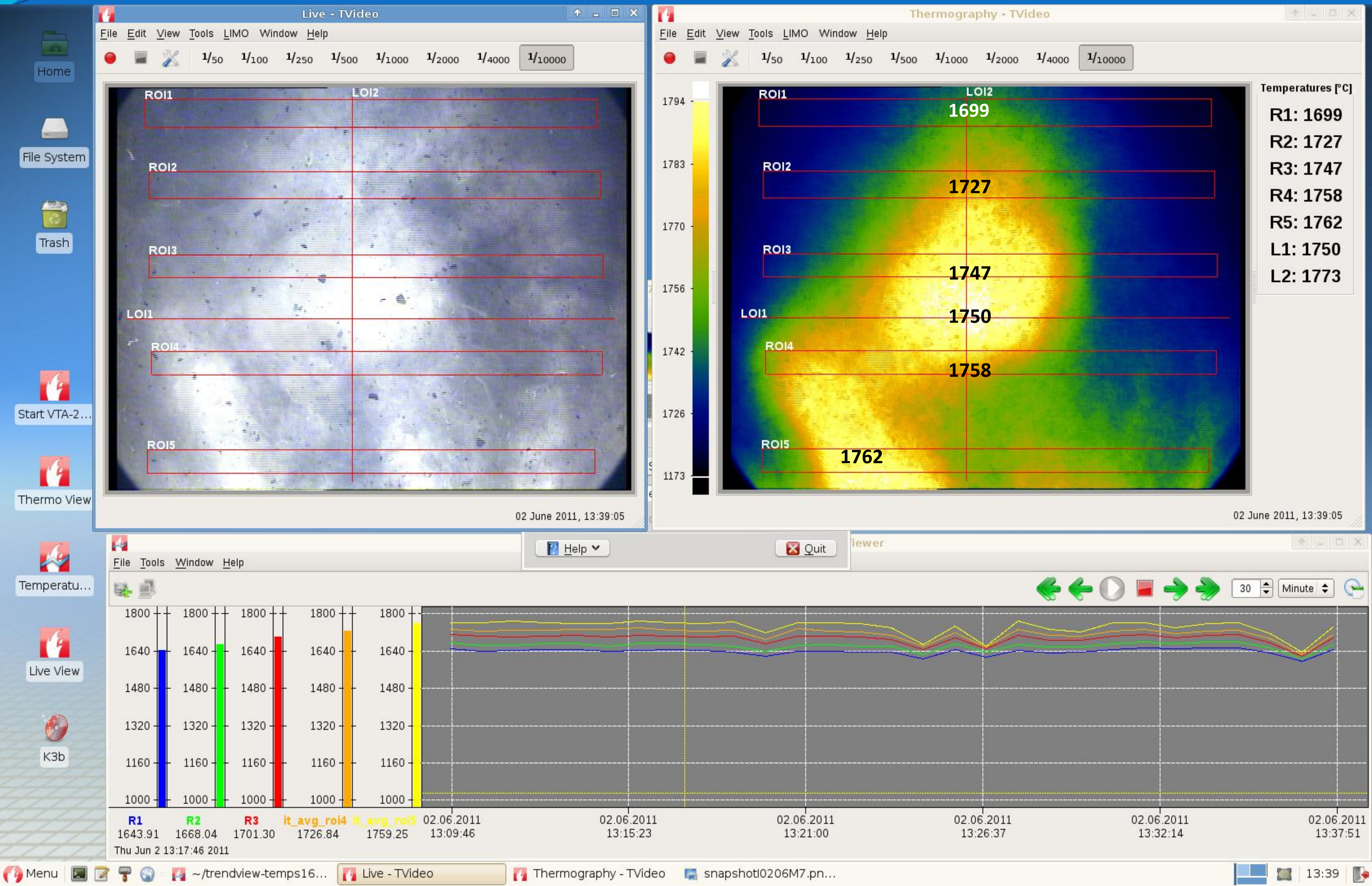
Grate fired – delayed combustion 1

COAL X - Sequence 1



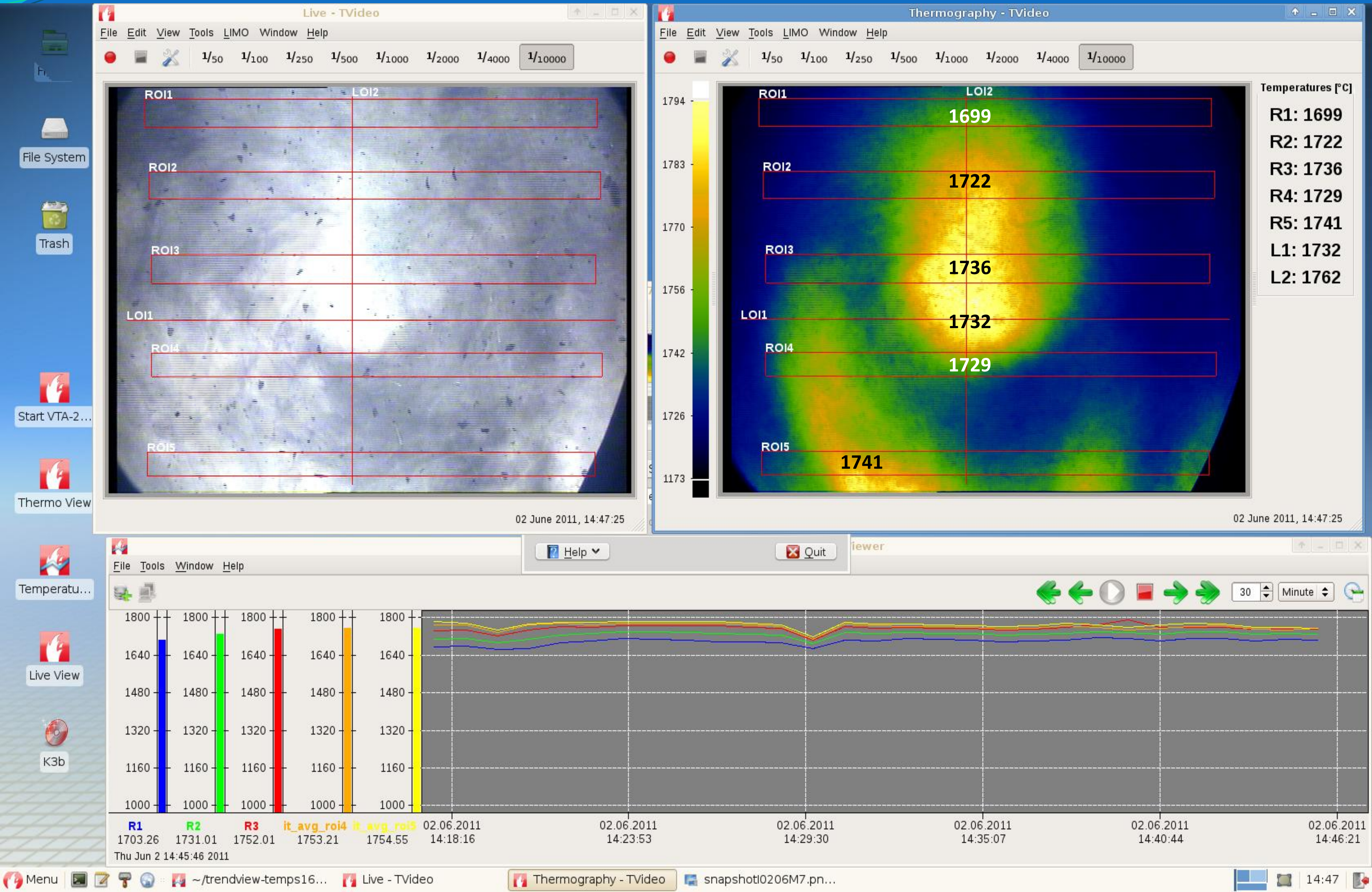
Grate fired – delayed combustion 2

COAL X- Sequence 2



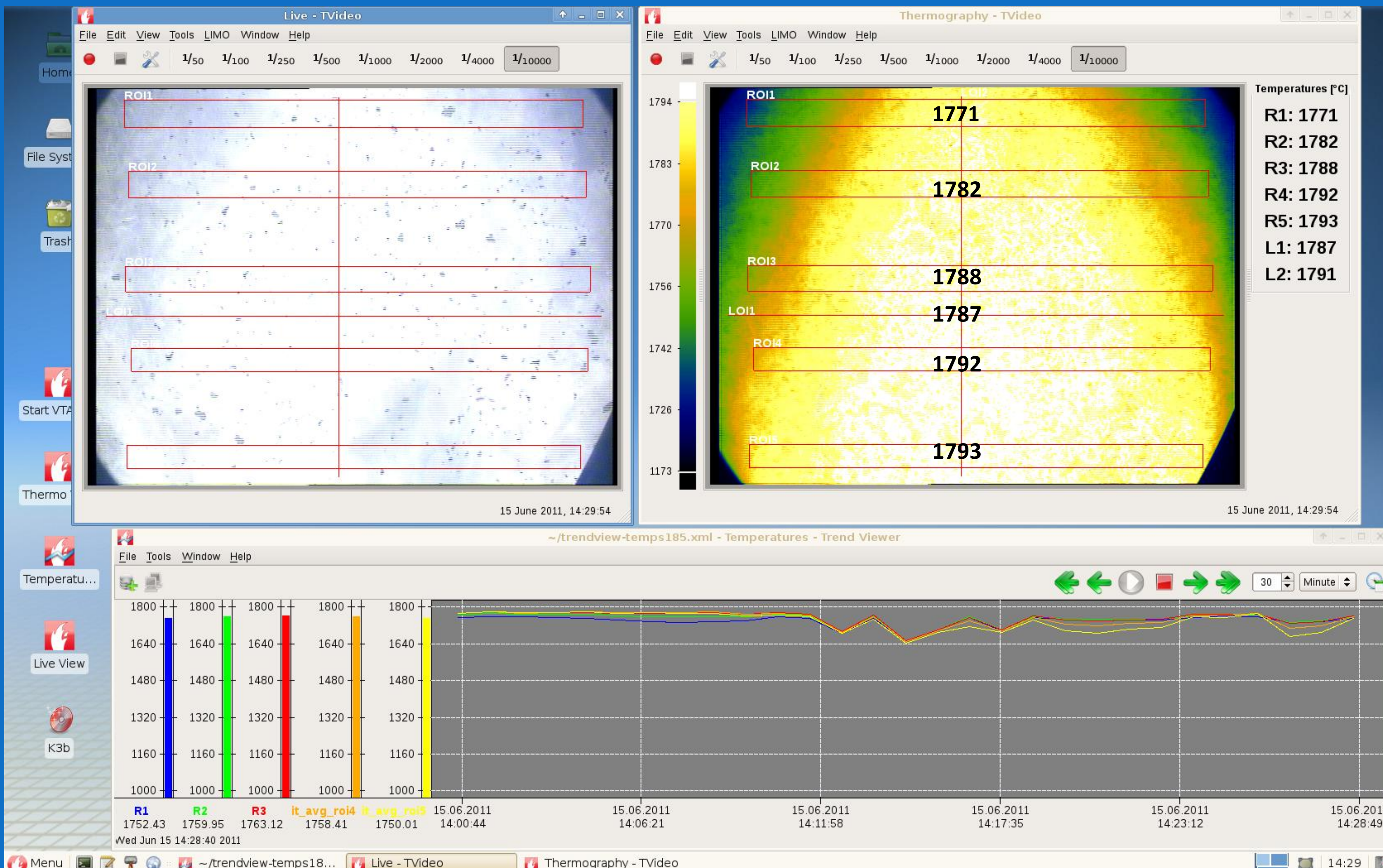
Grate fired – delayed combustion 3

COAL X- Sequence 3



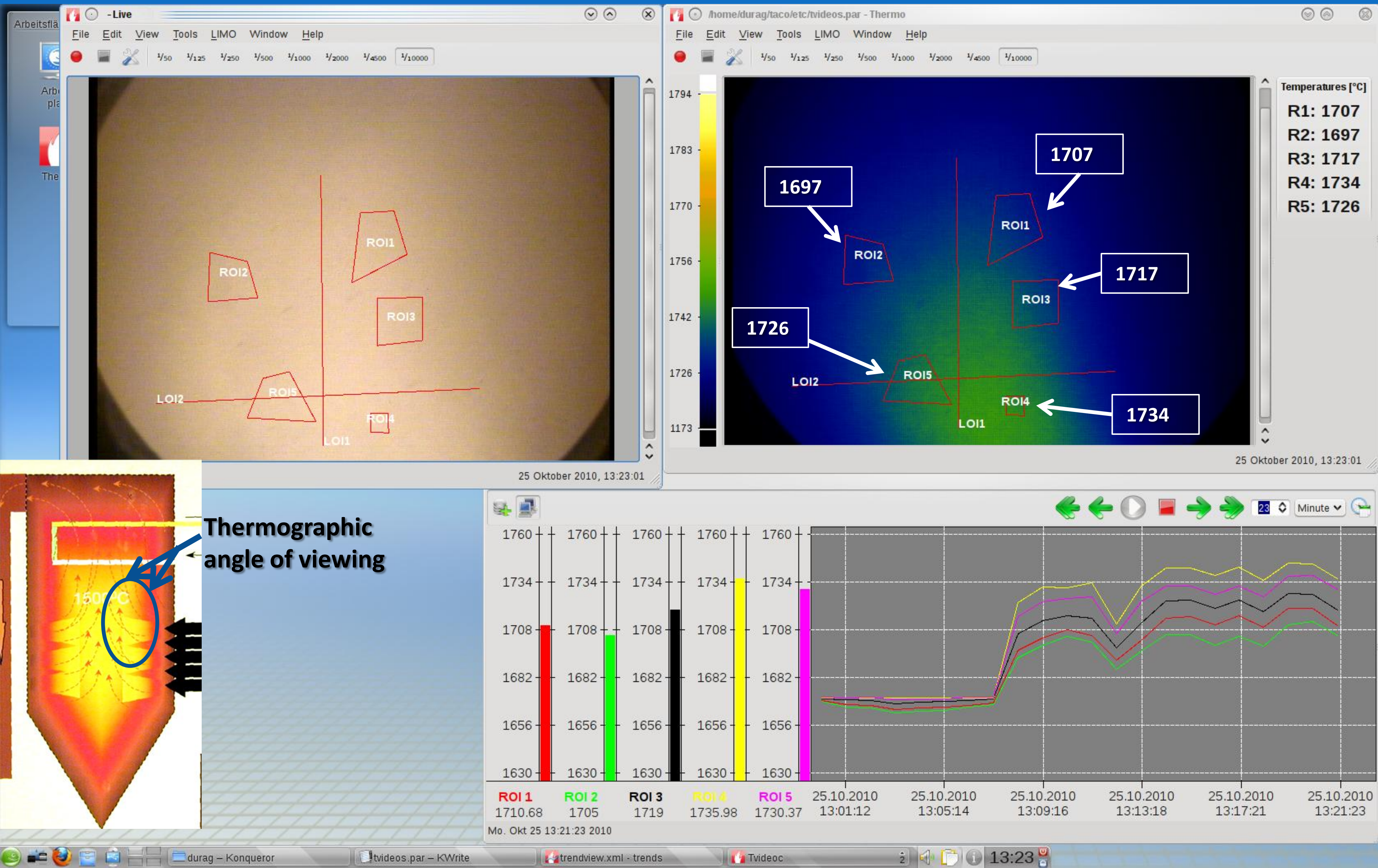
Grate fired – delayed combustion 4

COAL Z



PF-Boiler - Power station A

NB: Top of an off-centre fireball – temperatures 1700^{o}C ++



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Observations

- **Proximate (volatiles and ash analyses) and calorific value <u>alone do not indicate how coals will burn</u>, at what temperatures and for how long.**
- **There is clear evidence that <u>certain coals burn at higher temperatures</u> than was previously thought**
- **There is also clear evidence of <u>delayed combustion</u> – longer than previously believed**
- **These facts are likely to have <u>significant impact on boiler operation</u> and combustion efficiencies** *e.g.* ***Thermal damage to water tubes and superheaters, clinkering and excessive NOx formation***
- **These facts are likely to have <u>significant impact on future boiler design</u>,** *e.g.* ***Requiring high temperature steels in boiler manufacture***
- **Further work needs to be done to study combustion performance linked to more specific properties of coal and using thermography to control and achieve higher combustion efficiencies**

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Conclusions

- **Anomalous combustion behaviour can be explained**
  - By in-depth analysis of coals (petrographic composition)
  - By observation and monitoring *in situ* using on-line thermography
- **Combustion and thermal efficiency can be improved and controlled**
  - By monitoring combustion behaviour via thermography
  - By adjusting operating conditions in real time
- **Significant reductions in CO_2 and NOx emissions can be achieved**
  - by ensuring optimum combustion and burn-out
  - by maintaining maximum steam output
  - By reducing slagging, fouling and water tube failures and minimum outages

Energy – source of Industrialisation! Africa needs this….