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Energy efficient heat exchage and catalysis
The UNIHEAT Project

Cav Prof. Sandro Macchietto, Imperial College London

Energy & Water Security Workshop, Doha (Qatar) 15-17 February 2015

Myself

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- Chemical engineer
- Academic: Co-founder/director
    - Centre for Process Systems Engineering
    - Energy Futures Lab
    - Master in Sustainable Energy Futures
    - UNIHEAT
- Entrepreneurship:
  - Launched & managed 2 spinoffs
    - Process Systems Engineering Ltd
    - Hexxcell Ltd

Grand Challenge

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- Important
- Urgent

- Difficult
- Few clues
- Not in neat disciplinary boxes

Grand Challenge

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- Science (data, methods …)
- Industrial feasibility (scaling up, make..)

- Process, plant, people …
- Technical and economic performance
- Introduction, Impact

Q: What set-up to promote successful, rapid research, technology transfer, uptake ?

The Problem

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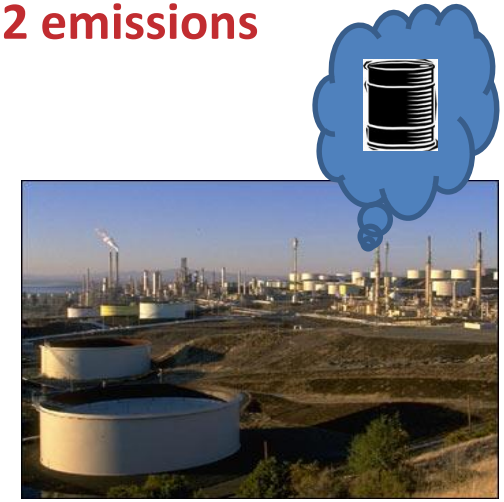
Oil Refineries use 5-7% of crude Oil to operate - World-wide >5m bbl/day !!

(Saudi Arabia production ~10m bbl/day)

2.5% of all man-made CO2 emissions

Crude oil



Refined products

Key refinery processes

Reaction and conversion → **Boreskov Institute of Catalysis**

wrong products, high temperatures

Thermal energy management → **Imperial College London**

fouling, poor energy integration

Refinery design and practice → **BP, Industry partners**

Support Service practice

The Opportunity

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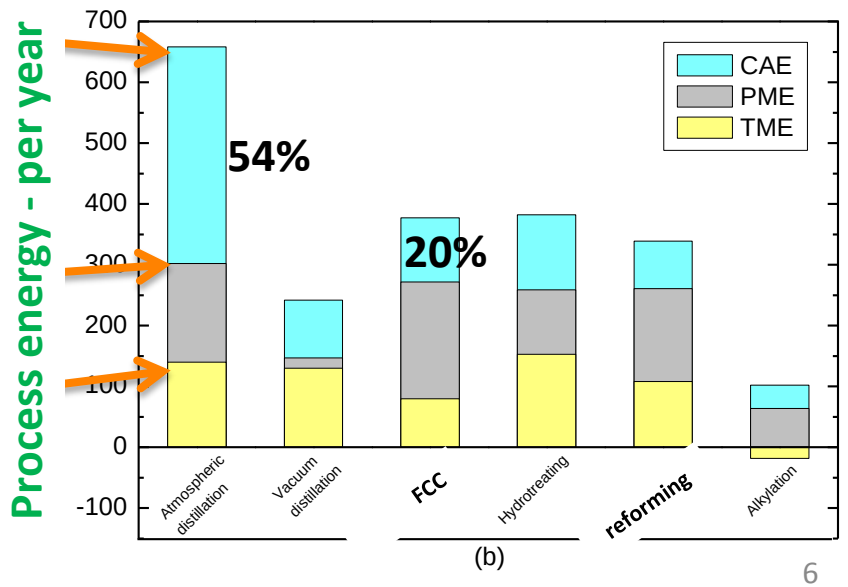
Overall, over 25% of refinery **energy losses** could be practically recovered.
In **some** process units **more than 50%** (US DOE 2006)

current average energy used

practical minimum energy

theoretical minimum energy required



The UNIHEAT Project

UNIHEAT

An international partnership between leading research institutions and industry

A well funded applied research programme with industrial engagement built-in

The largest interdisciplinary team anywhere in the world in this area

Innovation by design

www.uniheat-project.com

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Project partners

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Imperial College London is a science & engineering based institution consistently rated amongst the world's best universities.

Boreskov Institute of Catalysis is the world's largest research and development institution in the field of catalysis.

Novosibirsk State University is one of the best research and teaching institution organisation based in Novosibirsk, Russia.

UNICAT Ltd is a spin-off company that focuses on R&D activities in the fields of catalysis, engineering and energy efficient technologies.

BP is one of the world's largest oil companies serving customers every day in more than 90 countries across six continents.

Skolkovo Foundation is a Russian non-profit organization founded in 2010 to create a new science and technology development centre

The UNIHEAT research team

Name	Affiliation	Area of Expertise/Role
Prof. G.F. Hewitt	Imperial College London	Heat transfer, multiphase flow, nuclear power
Prof. G. Jackson	Imperial College London	Thermodynamics
Prof. S. Kazarian	Imperial College London	Advanced spectroscopic imaging, supercritical fluids processing
Prof. V.A. Kirillov	Boreskov Institute of Catalysis	Chemical engineering, heat and mass transfer, catalytic combustion
Prof. O.K. Matar	Imperial College London	Interfacial fluid mechanics, multiphase flow, first principle modelling
Prof. S. Macchietto	Imperial College London	Process Systems Engineering, UNIHEAT project co-director
Dr. C.N. Markides	Imperial College London	Heat transfer, thermodynamic cycles, energy conversion
Prof. O.N. Martyanov	Boreskov Institute of Catalysis	Catalysts and nanostructured materials physicochemical characterization, supercritical fluids , UNIHEAT project co-director
Dr. M. Millan-Agorio	Imperial College London	Catalytic upgrading of heavy oil, analytic characterization techniques
Prof. E. Müller	Boreskov Institute of Catalysis	Thermodynamics, Molecular simulation
Dr. A.V. Porsin	Boreskov Institute of Catalysis	Catalysts for air purification and fuel combustion, design of catalytic reactors, development of methods for testing catalysts and reactors
Dr. V.N. Snytnikov	Boreskov Institute of Catalysis	Catalysis, mathematical modelling, parallel algorithms, spectroscopy, chemical evolution, computational mathematics
Dr. V.A. Yakovlev	Boreskov Institute of Catalysis	Biofuels, hydrotreatment catalyst, combustion in FCB

+ PHd and MSc Students, Research Associates, Technicians

From molecular to plant scale

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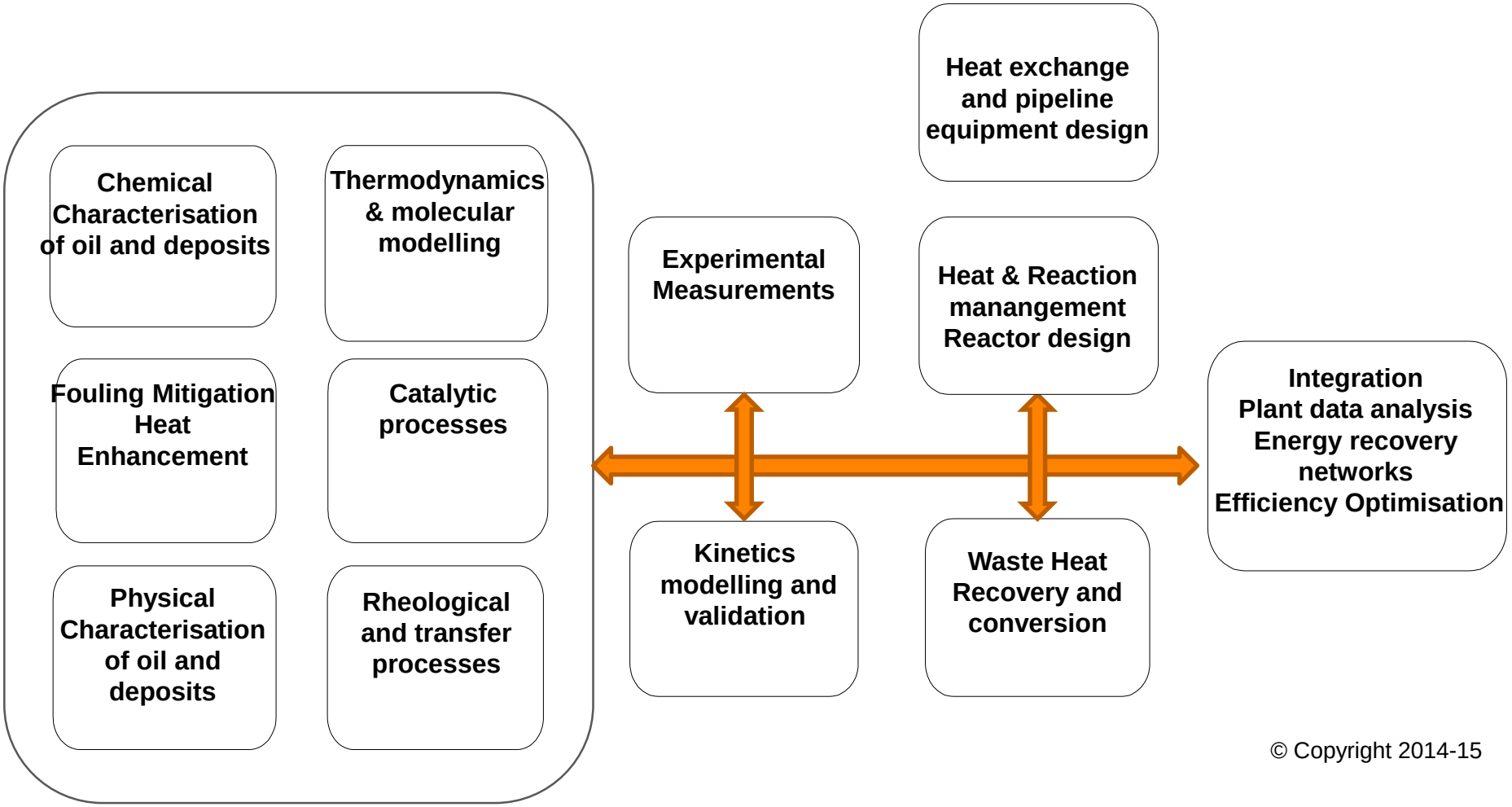

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6 UNIHEAT Research themes

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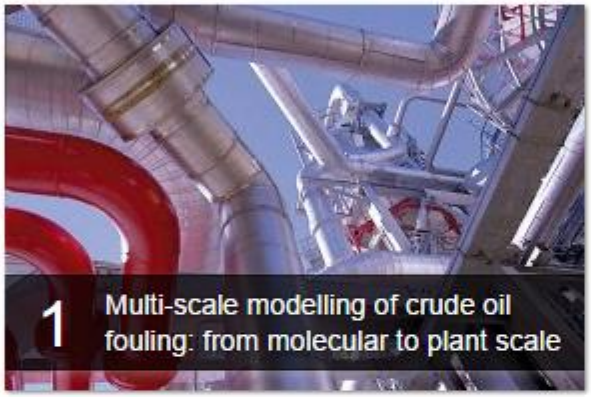

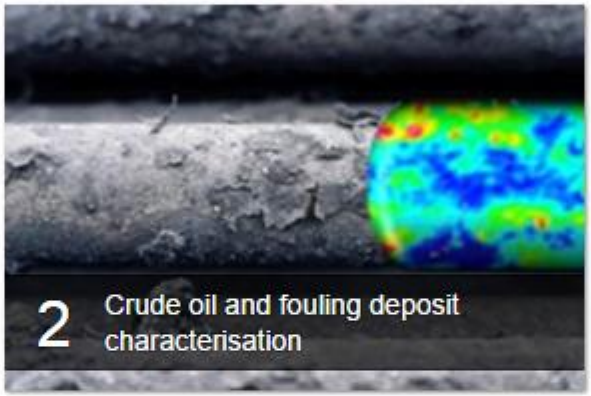

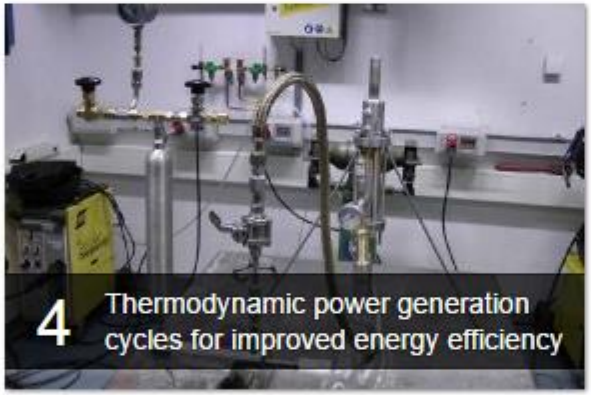

Theme 1 – Multi-scale modelling

properties, flow, equipment, efficiency

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Thermo & Molecular modelling
Prof. E. Müller and Prof. G. Jackson

Fundamental transport phenomena
Prof. O. K. Matar

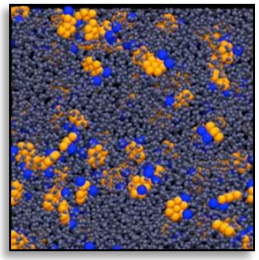
Industrial scale modelling
Prof. S. Macchietto

Experimental data

Equation of state

Parameters intermolecular potential

Molecular simulation



Properties of bulk fluids

Interfacial & transport properties

Heat balance

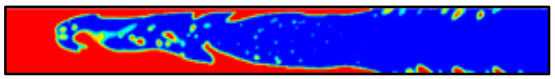
Momentum balance

Chemical reaction & equilibrium

Heat transfer coefficient

Shear stress & pressure drops

Fouling deposition & removal



Shell-side coupled to multi-pass tube-side model

Costing and impact model

Improved operations

Optimal design

Economical retrofit

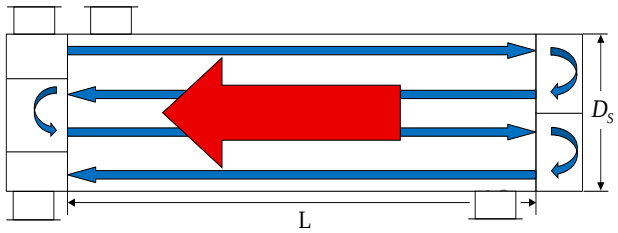


Image courtesy of Hexxcell ltd

State-of-the-art facilities

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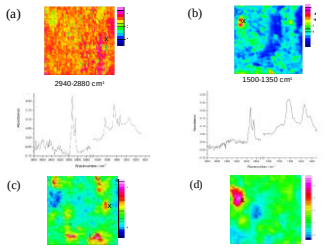
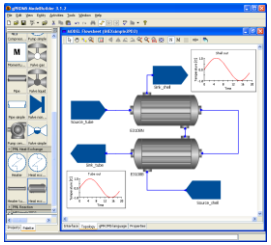


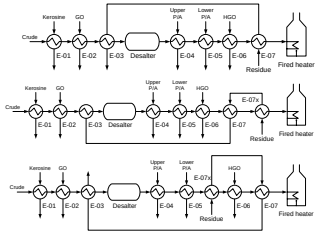
Imaging - FTIR spectrometer with Infrared Microscope and Macro Chamber
(128 x 128 infrared array detector)

HIPOR rig - Crude oil fouling measurement in industrial conditions

Catalytic reactions: partial oxidation of hydrocarbons ; thermocatalytic oxydation

High Performance computing and modelling





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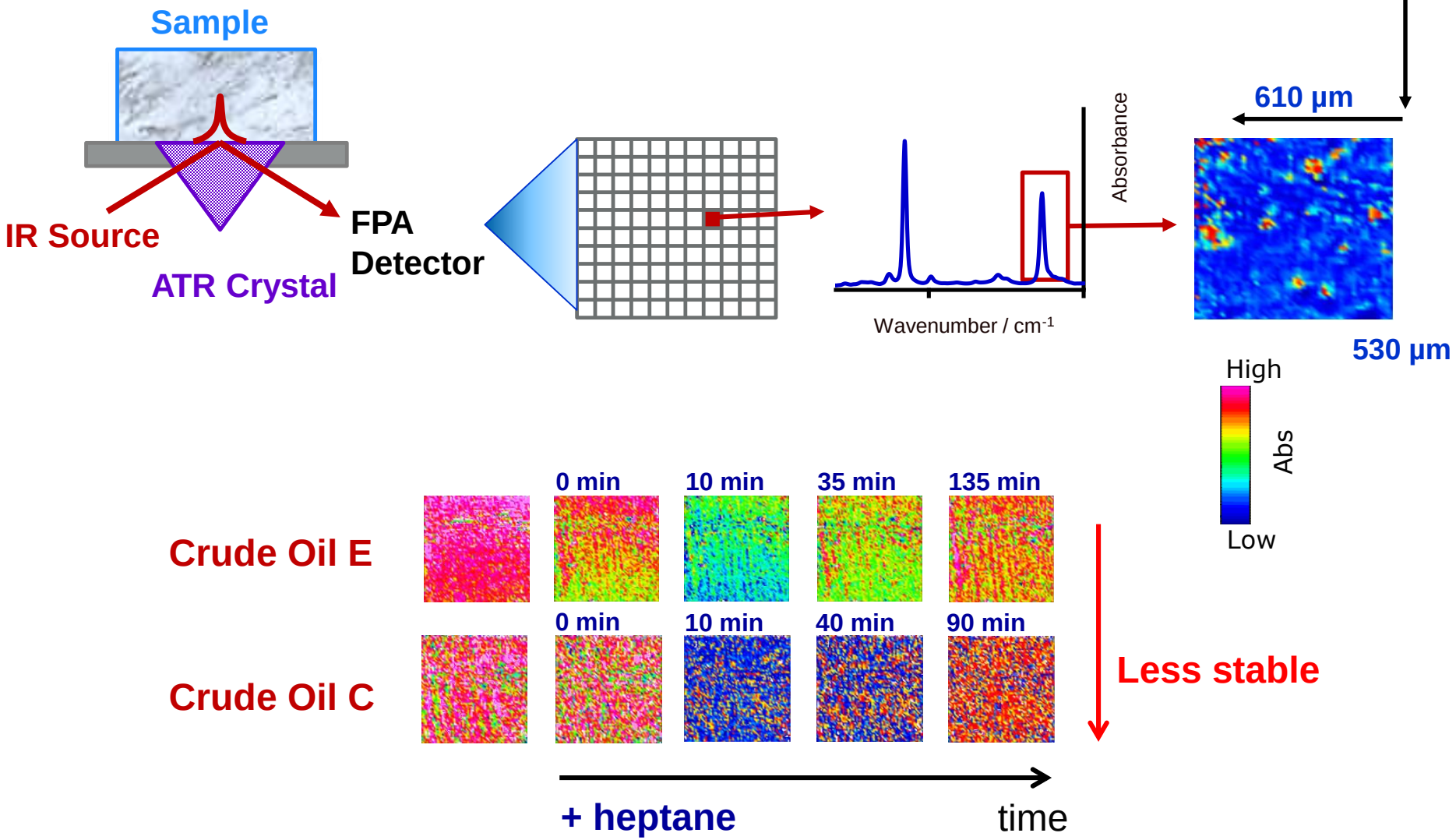
ATR-FTIR Spectroscopic Imaging (Chemical Imaging)



UNIHEAT Project - Industry engagement

Paul Docx
Managing Director
Imperial Consultants

Dr. Francesco Coletti
Industry Engagement Manager

Ivette Trinidad
Assist. Project Manager

3 Steps to Innovation™ – with industry

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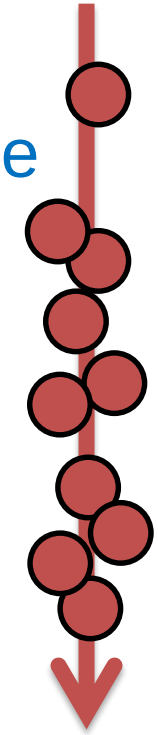
- Advanced Research
  methods, data, software
- Lab Demonstration
  small/medium scale
- Industrial feasibility
  full scale, real



Industry partners

Engagement
focus, trust, relevance

Data, materials
proof of concept

Plant, people
performance, benefit, ... steps for use

Greater probability of Technology Transfer success

Technologies pipeline

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- Fouling in oil refineries (measurement, modelling and mitigation)
- Crude oil characterisation
- Catalytic heating for pipelines and industrial heaters
- Catalytic combustion of heavy oils
- Heat recovery through catalytic Stirling engine
- Laser induced pyrolysis of light hydrocarbons

7 patents filed (5 + in preparation) , demonstrators, spinoffs …

Research to uptake

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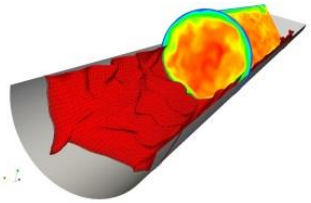

The UNIHEAT Office & Portal

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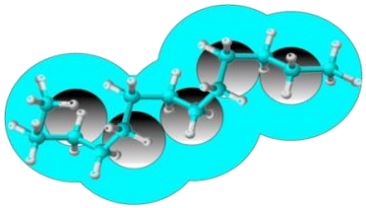

Fast track fundamentals served!

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ИК СО РАН

Novosibirsk State University
НГУ

UNICAT

bp

Sk Skolkovo

UNIHEAT

Contact

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Industry engagement:
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www.uniheat-project.com

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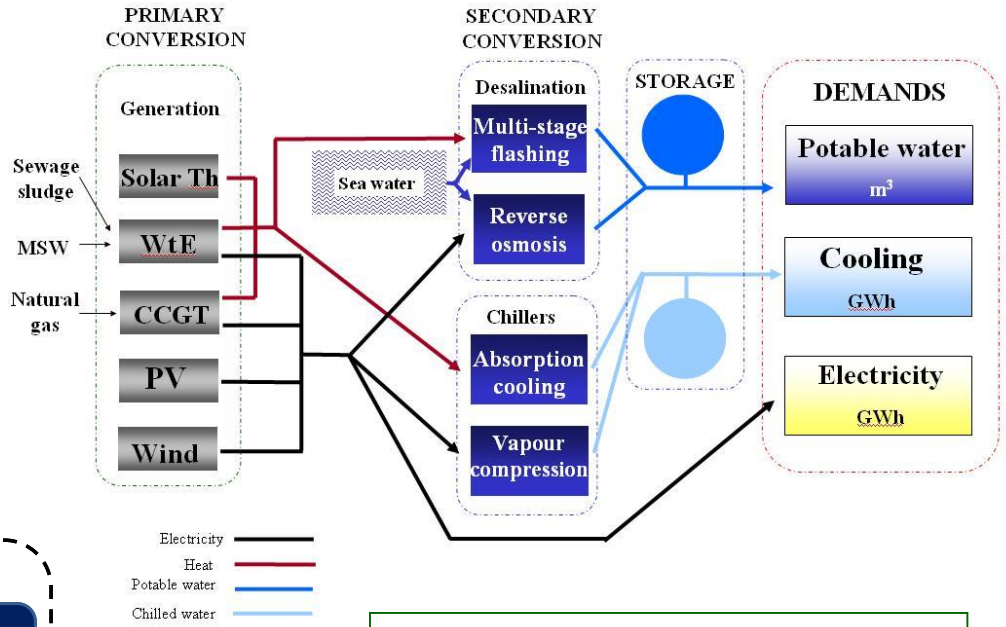
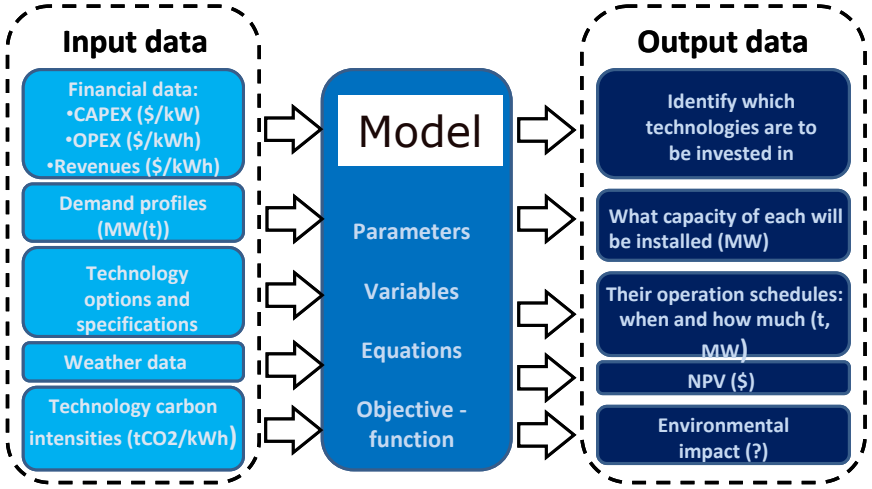
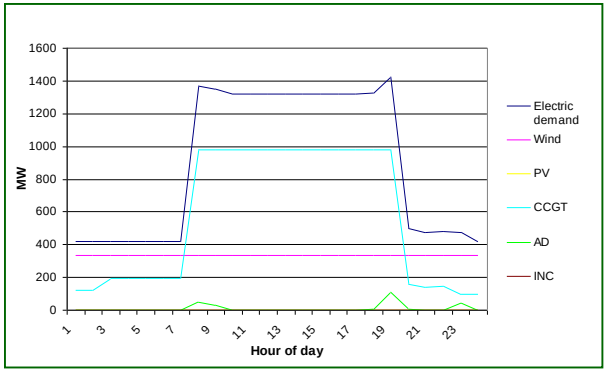
Utilities infrastructure for Dubai Waterfront Project

New urban development for 1.5m people with ARUP







Daily electricity generation mix for min emissions

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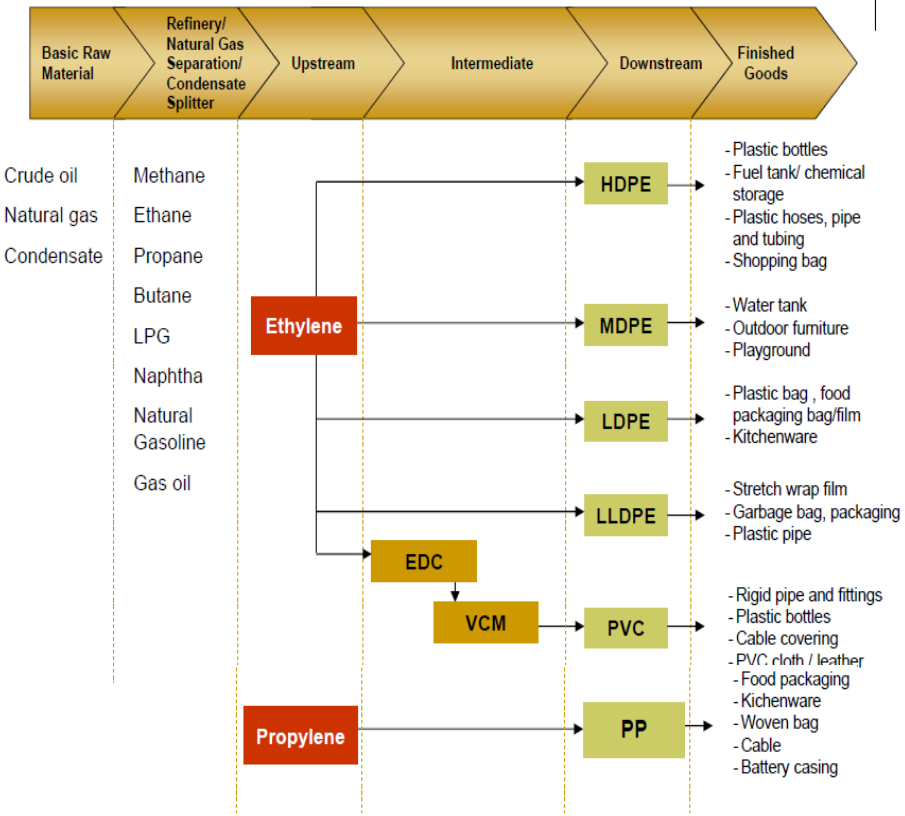
A new petrochemical complex for Vietnam

SCG SIAM CEMENT GROUP CHEMICALS



Ethylene

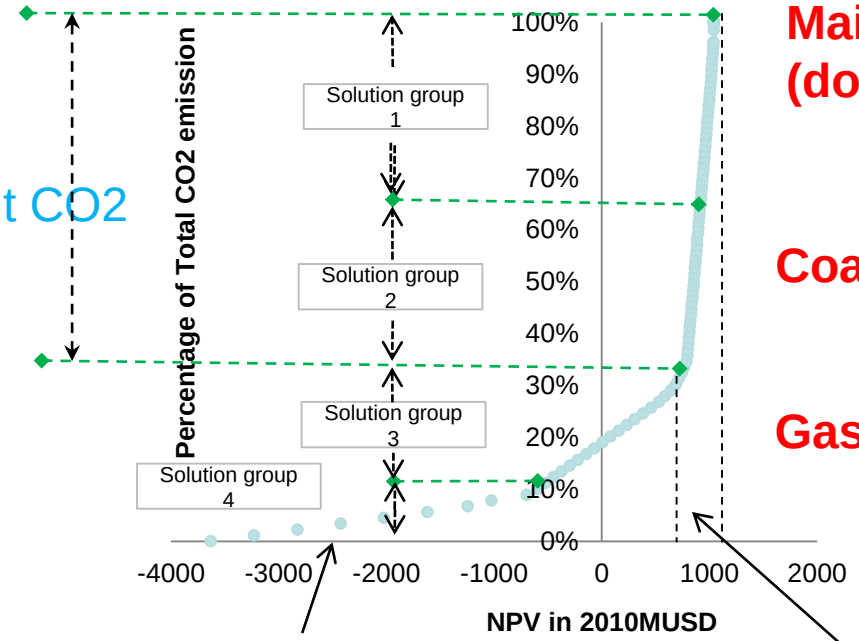
0.5 % of **global** energy consumption

35 MMTA of CO_2 emission

- Greenfield site
- Primary energy + sourcing
- Infrastructure (port, storage, ..)
- Several plants
- Energy, utility integration
- 30 yr plan
- **Max NPV Min CO_2**

Profit or environment?

Max NPV and Min TCO2



9.7 M t CO2

Mainly coal (domestic + regional +interregional)

Coal, Gas + electricity

Gas, electricity, biomass

$351M

Biomass + electricity

A CO2 price of 36$/t would give max NPV with 70% reduction of CO2

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Postgraduate training – MSc in Sustainable Energy Futures

MSc in Sustainable Energy Futures
Uniquely structured one year masters course for students from varying backgrounds

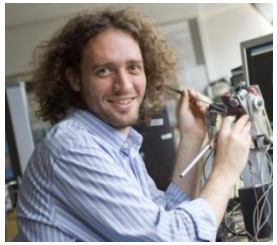
Highly interdisciplinary

Innovative format

“MBA for engineers”


Beetle hires sustainable energy expert

Mr Veys recently took time out from his money management career to do an MSc in sustainable energy futures at Imperial College London.



Conclusions

- Important ?
- Urgent ?

- Difficult ?
- Few clues ?
- Not in neat disciplinary boxes ?

LET'S START!