

*Le attività di ricerca e sviluppo nell'ambito
dell'industria di processo presso il DICI*

Dipartimento di Ingegneria Civile e Industriale



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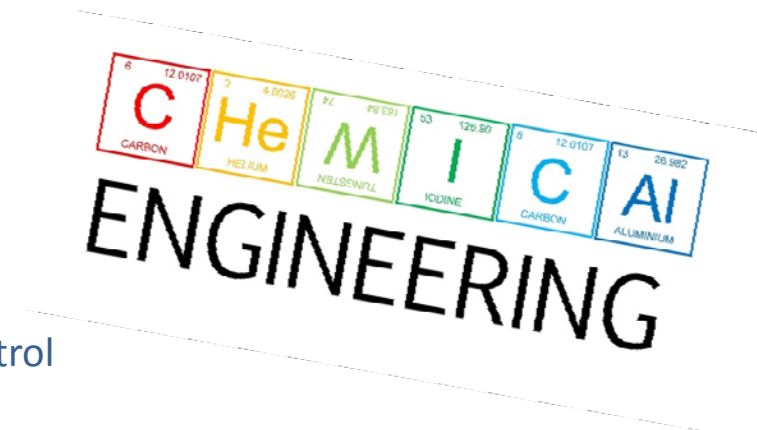
UNIVERSITÀ DI PISA
SCUOLA DI INGEGNERIA
DIPARTIMENTO DI INGEGNERIA CIVILE E INDUSTRIALE
SEZIONE INGEGNERIA CHIMICA

DIDATTICA

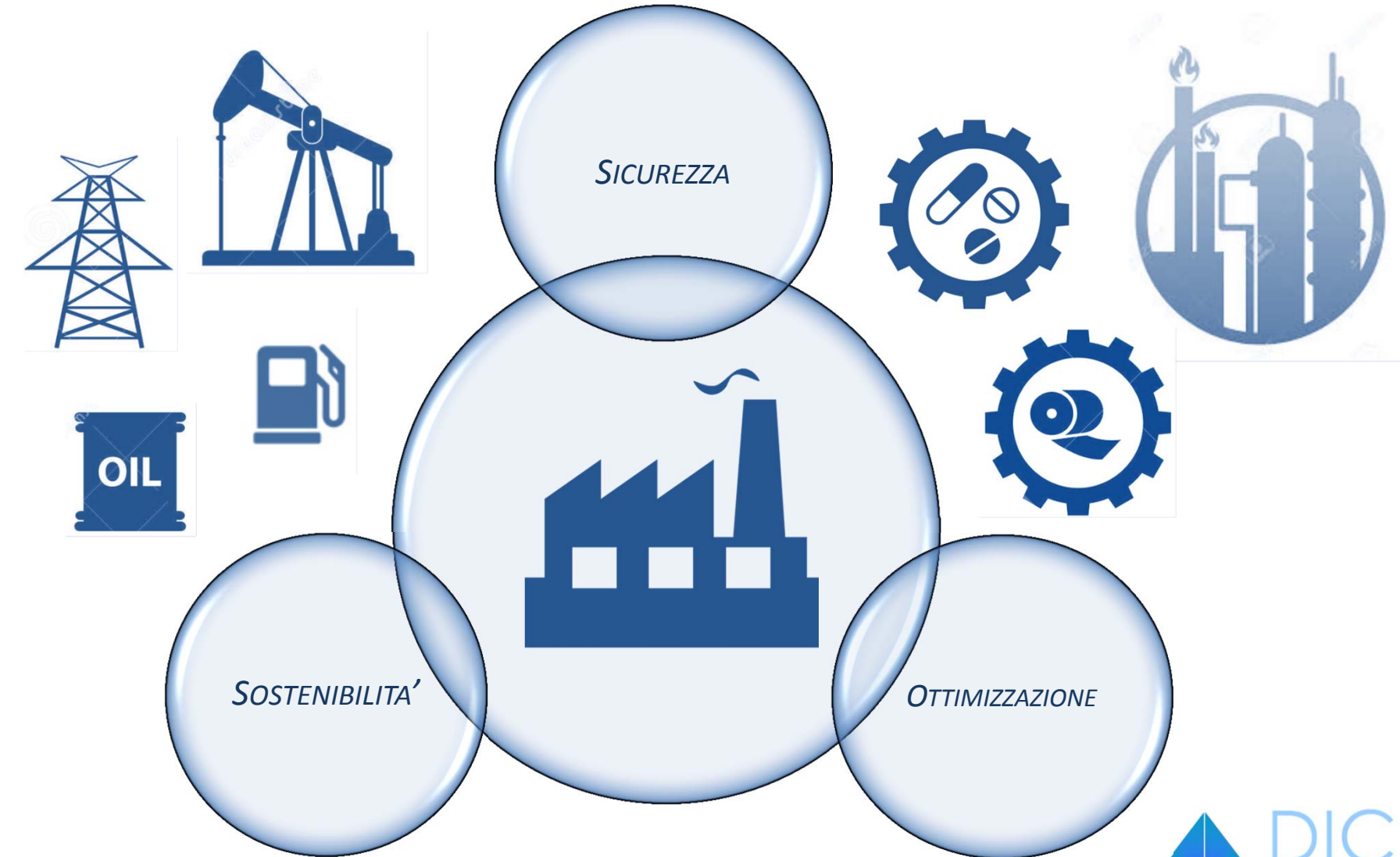
- Corso di Laurea in Ingegneria Chimica
- Corso di Laurea magistrale in Ingegneria Chimica
- Dottorato in Ingegneria Chimica e dei Materiali

RICERCA

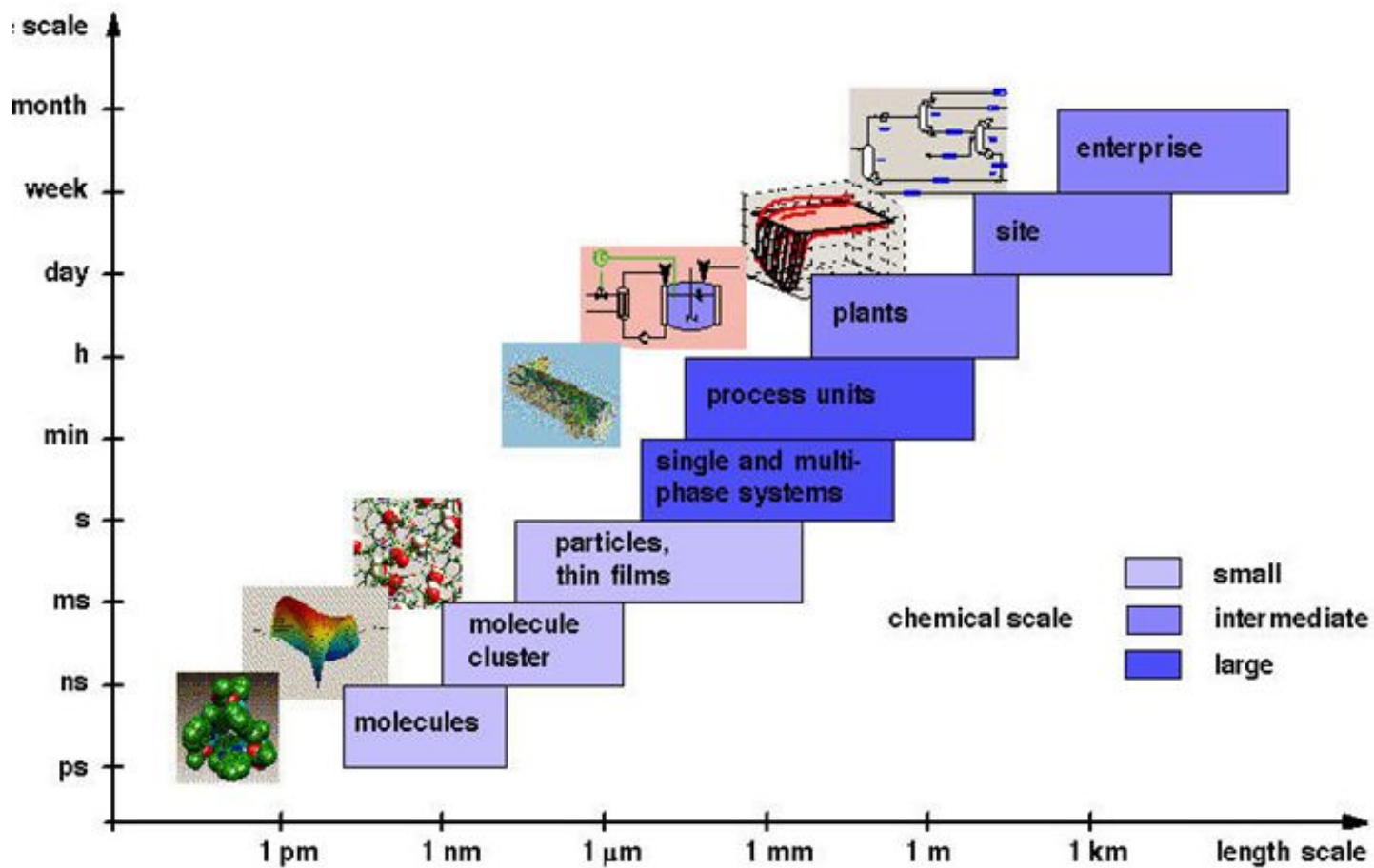
- Process unit operations
- Process design, simulation, optimization and control
- Heat and mass transfer
- Industrial reaction system design
- Integrated HSE (health, safety, environment) systems
- Material science and technology



*AMBITI DI RICERCA:
Innovazione di processo e di prodotto*



INGEGNERIA MULTISCALE



STUDIO SPERIMENTALE



LAB SCALE



PILOT SCALE



FULL SCALE



MODELLAZIONE NUMERICA

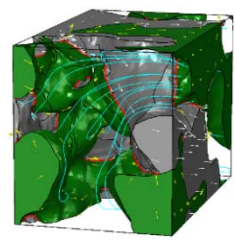
MODELLAZIONE MICROSCOPICA

- Microcinetica, microstruttura, mezzi porosi
- Software

COMSOL MULTIPHYSICS®

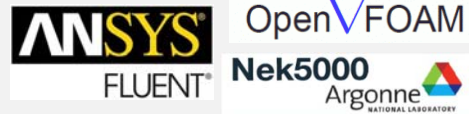


- Tomografia 3D



FLUIDODINAMICA COMPUTAZIONALE (CFD)

- Simulazione di flussi turbolenti, reattivi e multifase
- Codici



- Calcolo parallelo (in-house blade/clusters CINECA)



SIMULAZIONE DI PROCESSO

- Simulazione rigorosa stazionaria e dinamica
- Ottimizzazione numerica
- Linguaggi e codici:



UniSim® Design

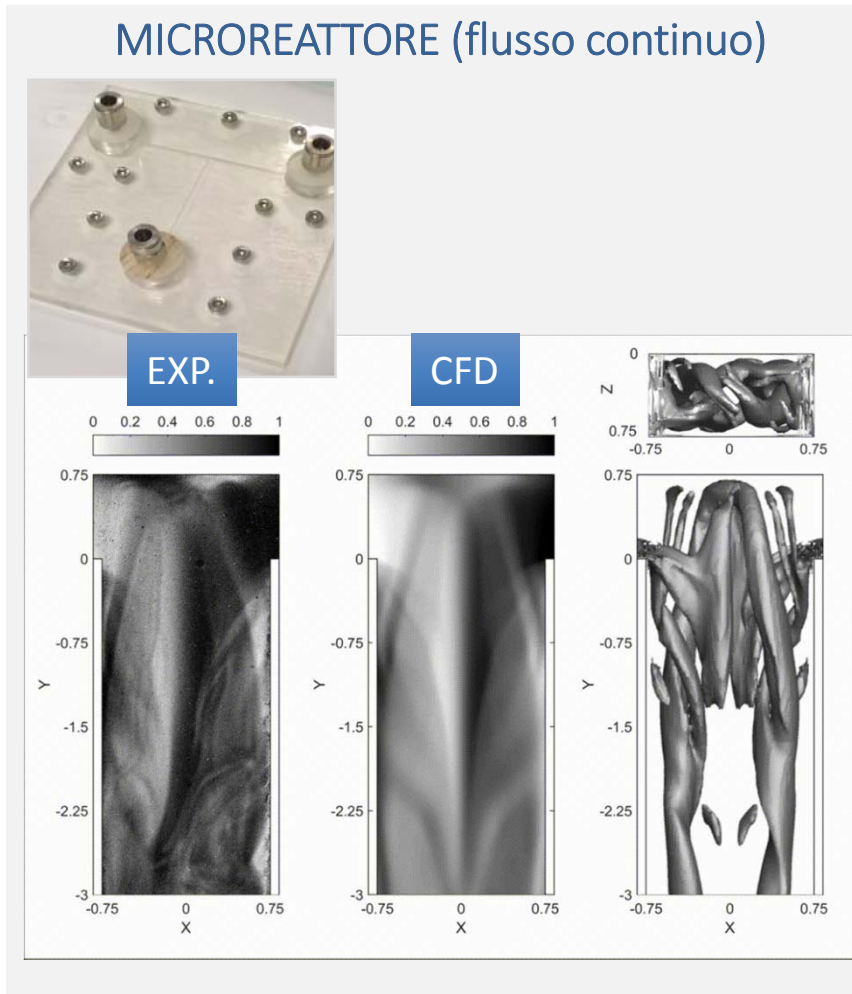
ANALISI DI SOSTENIBILITA' AMBIENTALE



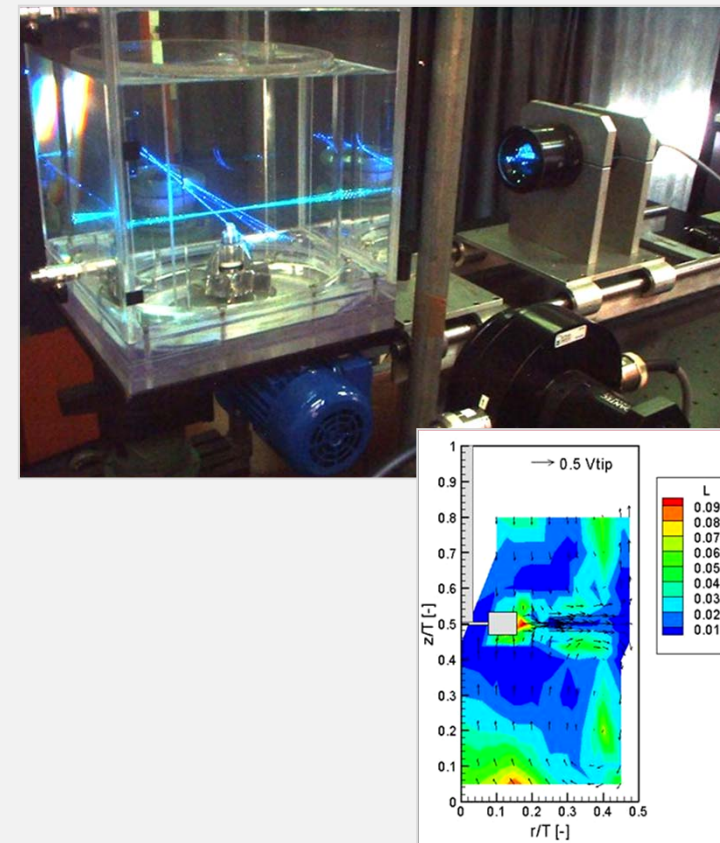
OTTIMIZZAZIONE

REATTORI: analisi sperimentale e modellistica di mixing e reazione

MICROREATTORE (flusso continuo)



REATTORE AGITATO (discontinuo)



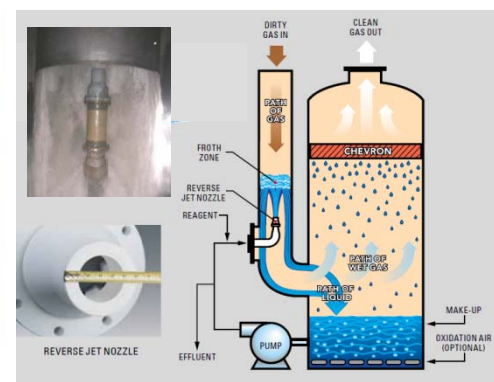
OTTIMIZZAZIONE

Analisi sperimentale e modellistica per l'ottimizzazione di apparecchiature.

Esempio: separatori per il trattamento di gas (jet-scrubbers, separatori inerziali per applicazioni navali, industria di processo, gas and oil, geotermico)

The collage illustrates the optimization of gas separators through experimental and modeling techniques. Key elements include:

- Schematic Diagram:** Shows the flow from a water tank through flowmeters and a liquid pump to an ultrasonic atomizer. The atomized liquid is injected into a separator box where it meets gas from an air inlet. The separator box includes optical access for a particle analyzer and is connected to a drain collector. Compressed air and a fan are also part of the system.
- 3D Simulation:** A velocity field simulation showing flow patterns in a curved duct, with a color scale for velocity ranging from 0.000000 to 1.000000.
- Industrial Facility:** A photograph of a large industrial plant, likely a geothermal or gas processing facility, with steam rising from a large tank.
- Separator Diagram:** A detailed cross-section of a separator showing zones for dirty gas in, clean gas out, froth zone, reverse jet nozzle, reagent, and liquid. It also indicates the location of a pump, effluent, and optional oxidation air.
- Logos:** ENGIE Axima, AWS CORPORATION, and CHANTIERS DE L'ATLANTIQUE.
- Other Images:** A photograph of an offshore oil platform and a cruise ship (MSC).



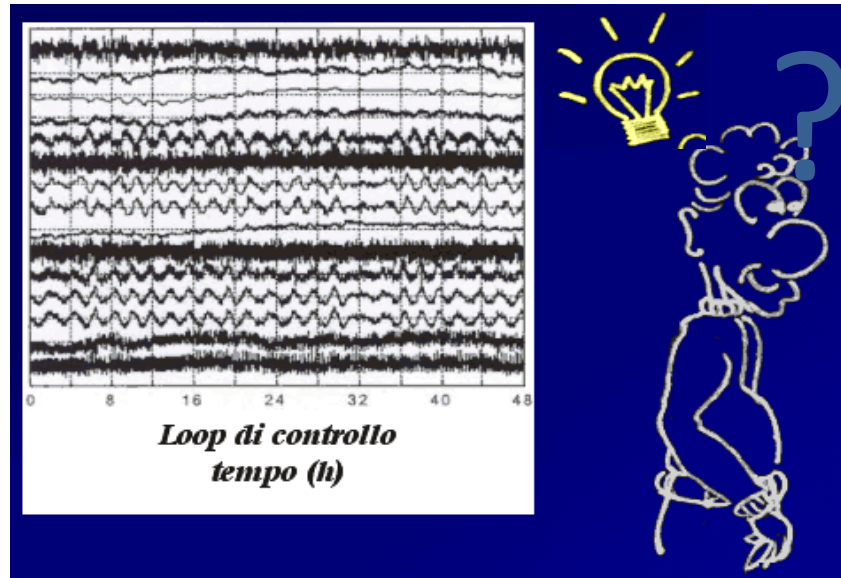
OTTIMIZZAZIONE- Industria 4.0



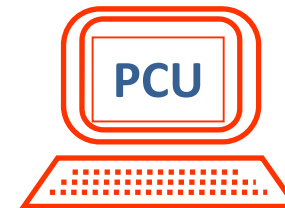
Monitoraggio delle prestazioni

Progettazione di un pacchetto software

Monitoraggio delle prestazioni dei regolatori e analisi delle anomalie



Suggerimento di strategie operative che facilitino il compito dell'operatore



- **Applicazioni:** raffinerie ENI, centrali ENEL, impianti soci CLUI
monitoraggio loop di regolazione: tuning controllori e manutenzione valvole
- **Estensioni:** diagnostica di sistemi e componenti
indici di prestazione globali dell'impianto (economici & ambientali & energetici)
indici di status delle apparecchiature (integrità, invecchiamento ...)

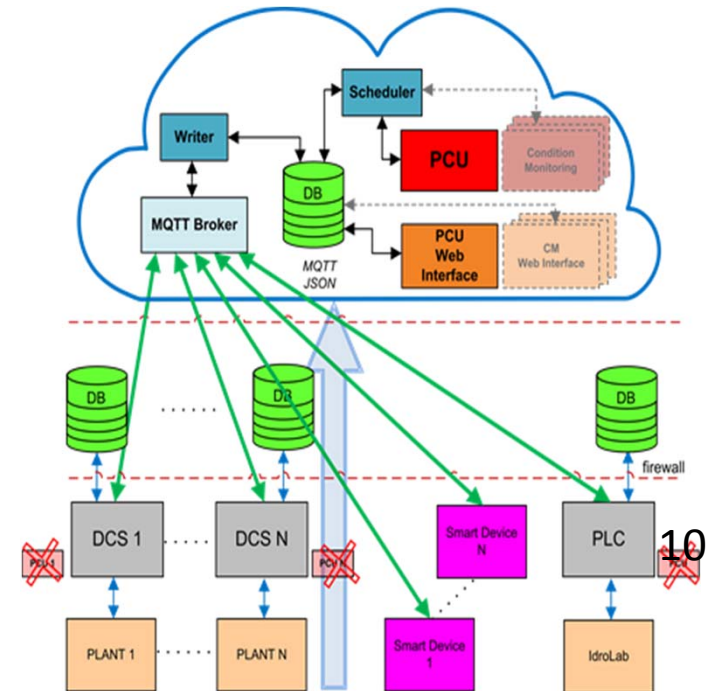


OTTIMIZZAZIONE- Industria 4.0



Dimostratore di tecnologie

CLUI
Automazione e Strumentazione



Impianto pilota IdroLab 4.0

Oggi:

Monitoraggio in Cloud di loop di controllo (PCU-Cloud)

Prossimamente:

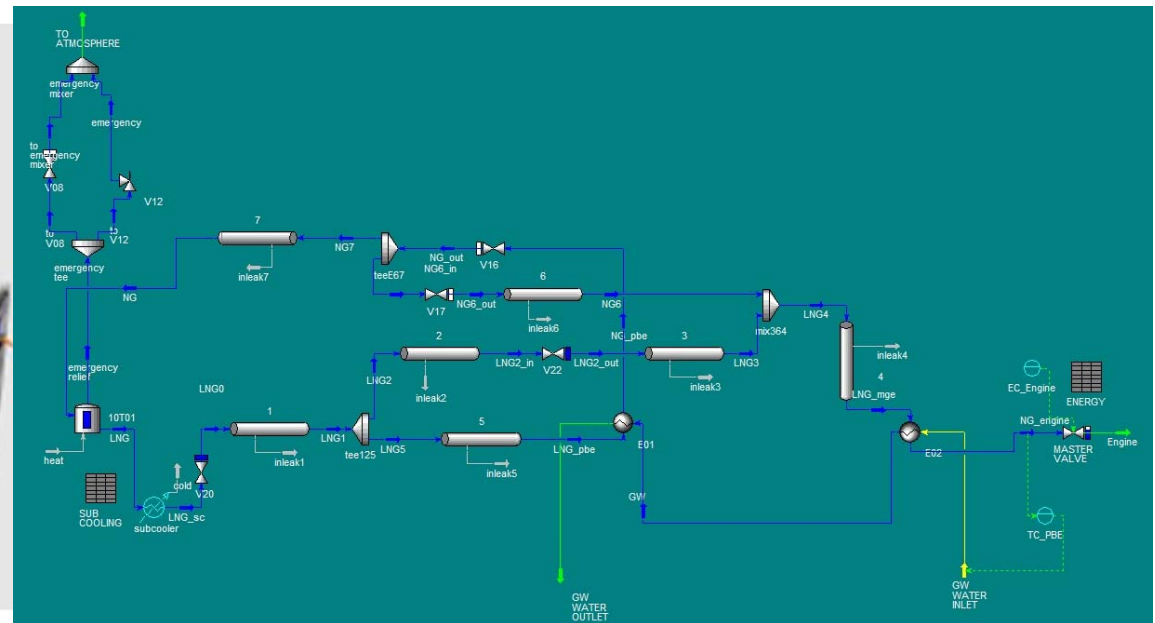
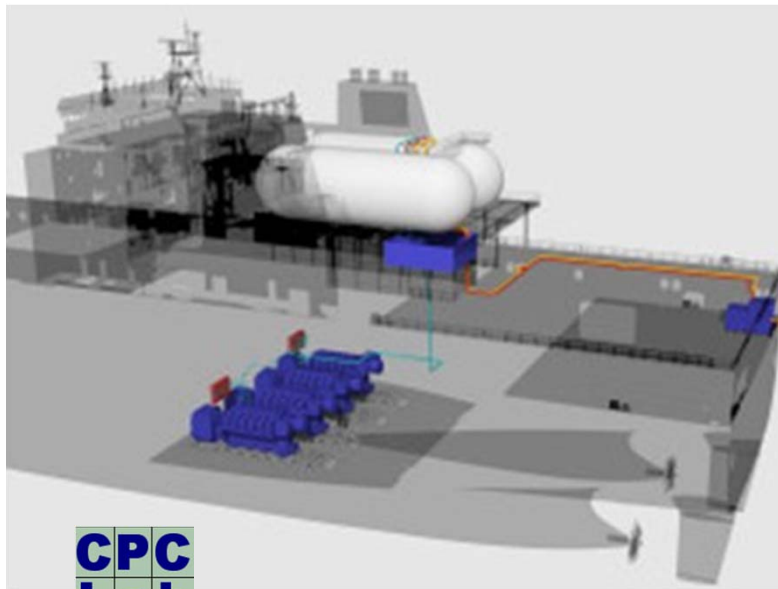
- Implementazione del prototipo in Impianto Enel:
monitoraggio valvole di regolazione
- Monitoraggio Globale:
consumi energia, vibrazioni, emissioni

OTTIMIZZAZIONE- Industria 4.0

Simulazione rigorosa di processo

- Sviluppo di modelli di simulazione per sistemi complessi
- Ottimizzazione energetica, economica
- Certificazione di operabilità e sicurezza

Esempio di applicazione: simulazione dinamica di un LNG Fuel system



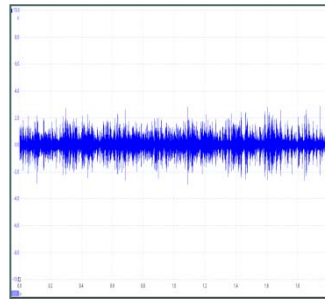
OTTIMIZZAZIONE: Industria 4.0

REATTORI: misure avanzate e algoritmi machine learning per applicazioni industriali

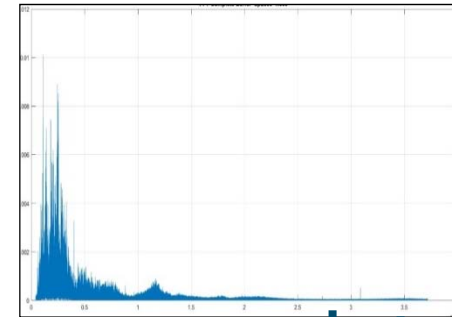
External passive AE sensor



Acoustic signal- TIME DOMAIN



Acoustic signal FREQUENCY DOMAIN



- Identify solid-liquid flow regimes
- Define the *Flow Map*

I STEP
• Spectra Analysis
• Images Analysis

- *Classification learning* in order to predict physical properties

II STEP
Machine Learning



UNIVERSITY OF BIRMINGHAM



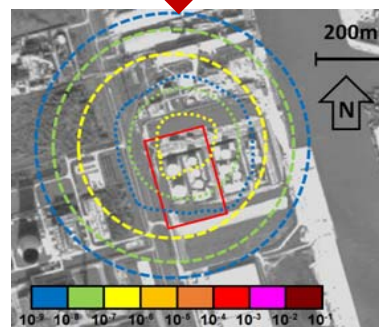
SICUREZZA

Sicurezza degli stabilimenti chimici e trasporto merci pericolose

Analisi del rischio

Direttiva SEVESO III – RdS

- *Analisi conseguenze*
- *Rischio individuale, sociale*
- *Matrici di rischio, metodi avanzati*



Caratterizzazione sostanze pericolose

Low phi-
factor
adiabatic
calorimeter
(PHI-
TECH2)

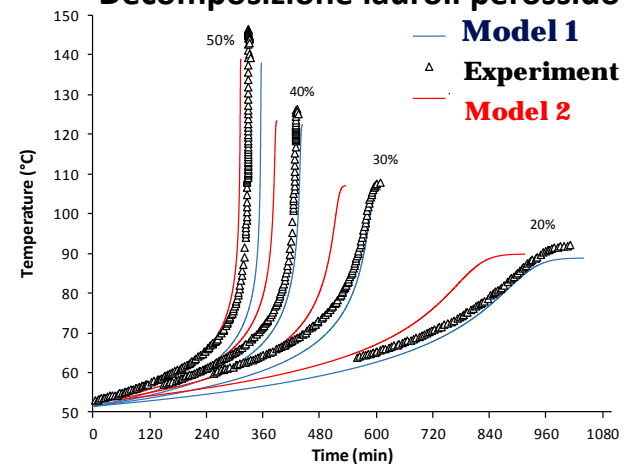


OPERATING RANGE

Temperature: 25 – 400 °C

Pressure: 0 – 137 bar

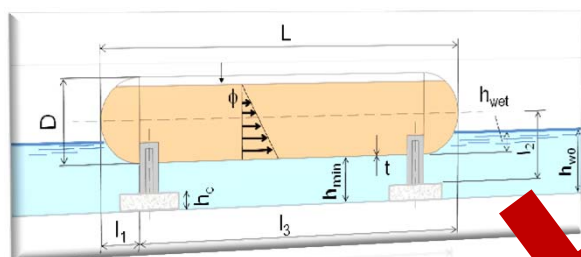
Decomposizione lauroil perossido



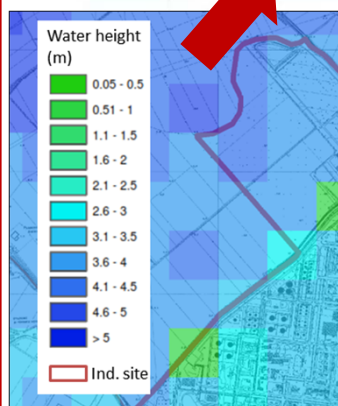
SICUREZZA

Analisi di rischio in stabilimenti chimici - eventi esterni

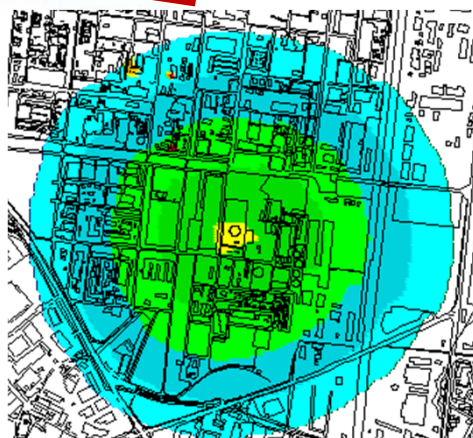
NaTech – Natural technological events
Impatto di eventi naturali su impianti chimici



Modelli di danno per apparecchi chimici
(causati da inondazioni)

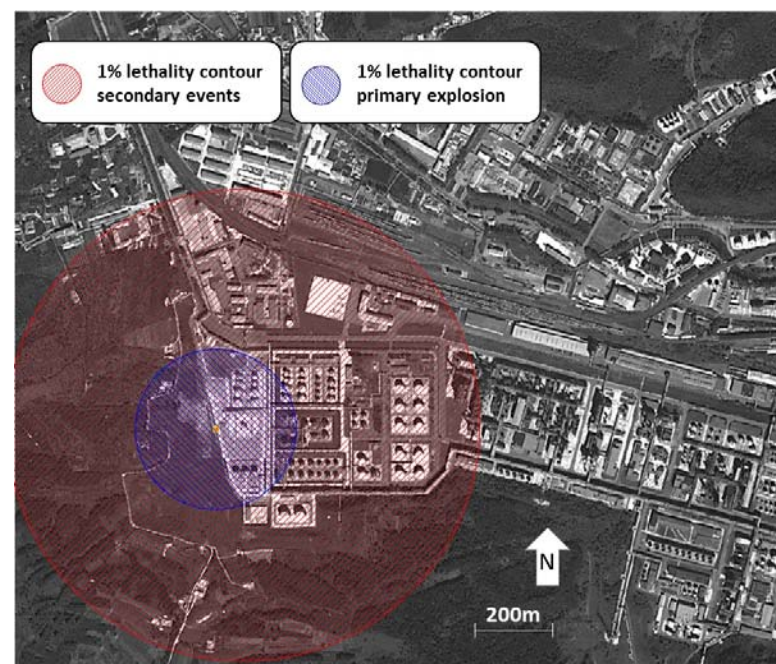


Studi idrogeologici



Analisi rischio indotto

Security vulnerability assessment
Attacchi terroristici ad impianti chimici



Attacco mediante esplosivo IED (improvised explosive devices) ad unità di processo

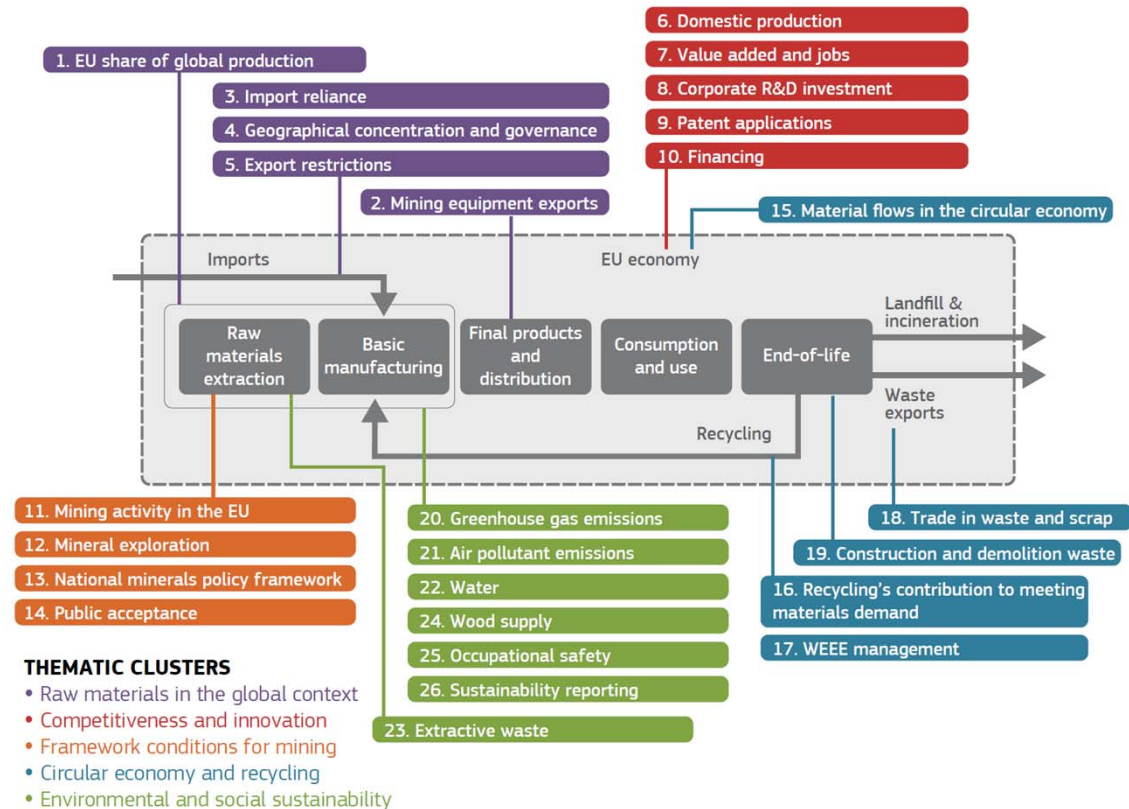
Circular Economy & Material Cycles

The Raw Materials Scoreboard 2018 - RMIS.

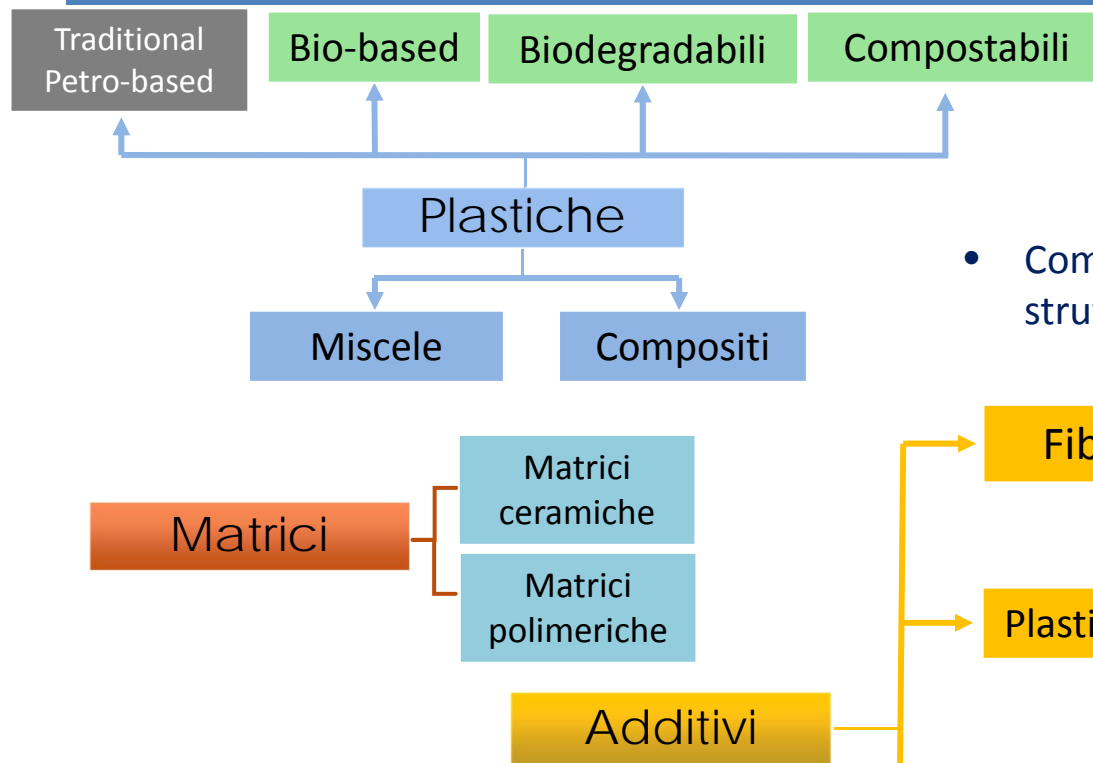


DICI, in particular the [chemical and materials engineering section](#), has been involved in international and national research projects concerning different aspects of primary and secondary raw material cycle that can have considerable impacts in the supply chain, such as product design phase, production processes, consumption patterns and so on. The issues were, among others,

- [better product design](#) that can make products easier to be disassembled and recycled and hence can help recyclers to recover valuable materials and components;
- [develop of products](#) making sure that significant quantities of recycled materials and/or of re-used components are integrated into new products;
- [adjustments/optimisation of the production processes](#) and advanced work with the material/component supply chain to reduce the quantity of generated waste;
- development of high quality Secondary Raw Materials [recovery strategies](#) and processes from industrial wastes.



OTTIMIZZAZIONE: innovazione di prodotto



Sviluppo, ottimizzazione e caratterizzazione di materiali per vari settori: automotive, packaging, biomedico, agricoltura, ...

- Comprensione e controllo delle proprietà strutturali di polimeri e compositi

- Fibre naturali (legno, lino, cellulose ..)
- Fibre di carbonio
- Fibre da scarti agro-alimentari

- Reattivi (etere diglicidilico, cardanolo, ...)
- non reattivi (ATBC, PEG,...)

- Indurenti per gomma (PBAT, PBSA)
- Indurenti rigidi (CaCO₃ stearato, argille)

- Melt Enhancers (Plastistrength)
- Estensori di catena (Joncryl)
- Agenti nucleanti (Talco, LAK, ...)
- Agenti antiscivolo (Erucamide)
- Rinforzi (CaCO₃)

- Produzione di blends e compositi a base di **bioplastiche**, biodegradabili, in alternativa alle plastiche derivati dal petrolio per varie applicazioni.
- Miglioramento delle proprietà meccaniche e termiche dei compositi a base di **tecnopolimeri** e di **materiali ceramici**.
- Sviluppo di nuovi materiali per applicazioni biomedicali (drug delivery, **ingegneria tissutale**)

Ottimizzazione di formulazioni a base di polimeri termoplastici

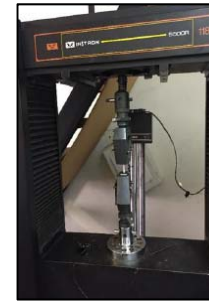
Processing

Estrusione
su scala Lab e pilota
Estrusione in bolla
Cast extrusion
Stampaggio a iniezione



Testing

Test meccanici
(Tensili e Charpy)
Analisi termica
(TGA, DSC)
Analisi morfologica
Analisi DMTA
Prove Reologiche
Compostabilità



Produzione

CaCO₃ nanoparticellare
Nanofibre mediante
electrospinning



Innovazione di prodotto per la sostenibilità



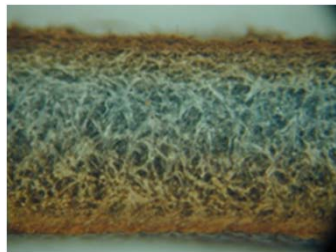
Prodotti stampati e packaging basati su formulazioni ottimizzate a base di materiali **compostabili** e biodegradabili **in terreno** e in **acqua di mare**.

SOSTENIBILITA': innovazione di processo

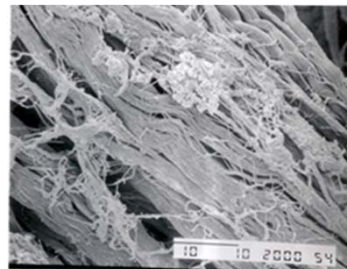
Sviluppo di processi innovativi



Lab Scale



Pilot Scale



Full Scale

Esempio: Settore Conciario



PO.TE.CO.
POLO TECNOLOGICO CONCIARIO

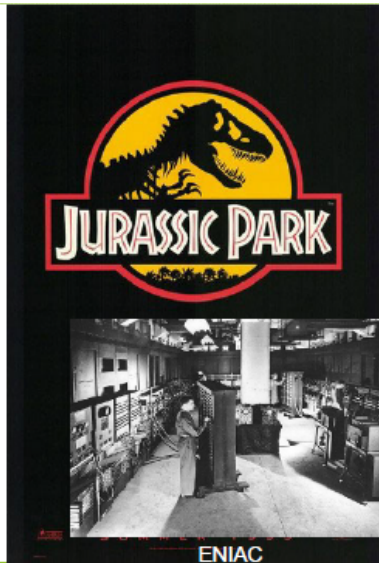


ITALPROGETTI
engineering



SOSTENIBILITA'

Intensificazione di processo: apparecchiature e metodi.



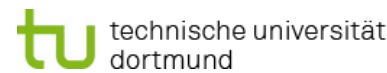
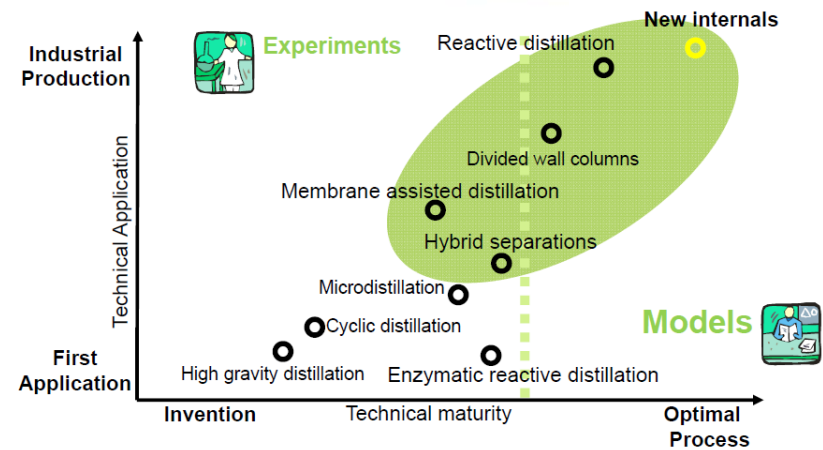
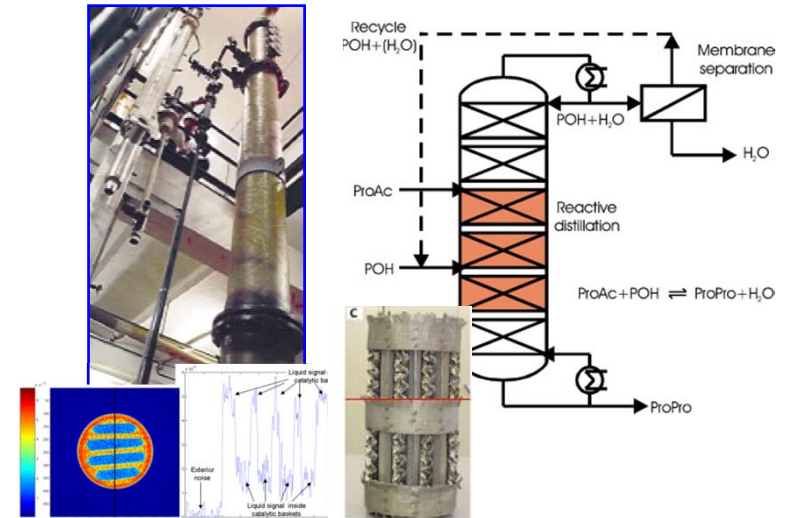
What is Process Intensification (PI)?

A strategy for making dramatic reductions in the size of a chemical plant so as to reach a given production objective – Ramshaw 1995

Any chemical engineering development that leads to a substantially smaller, cleaner, and more efficient technology is process intensification – Stankiewicz 2000

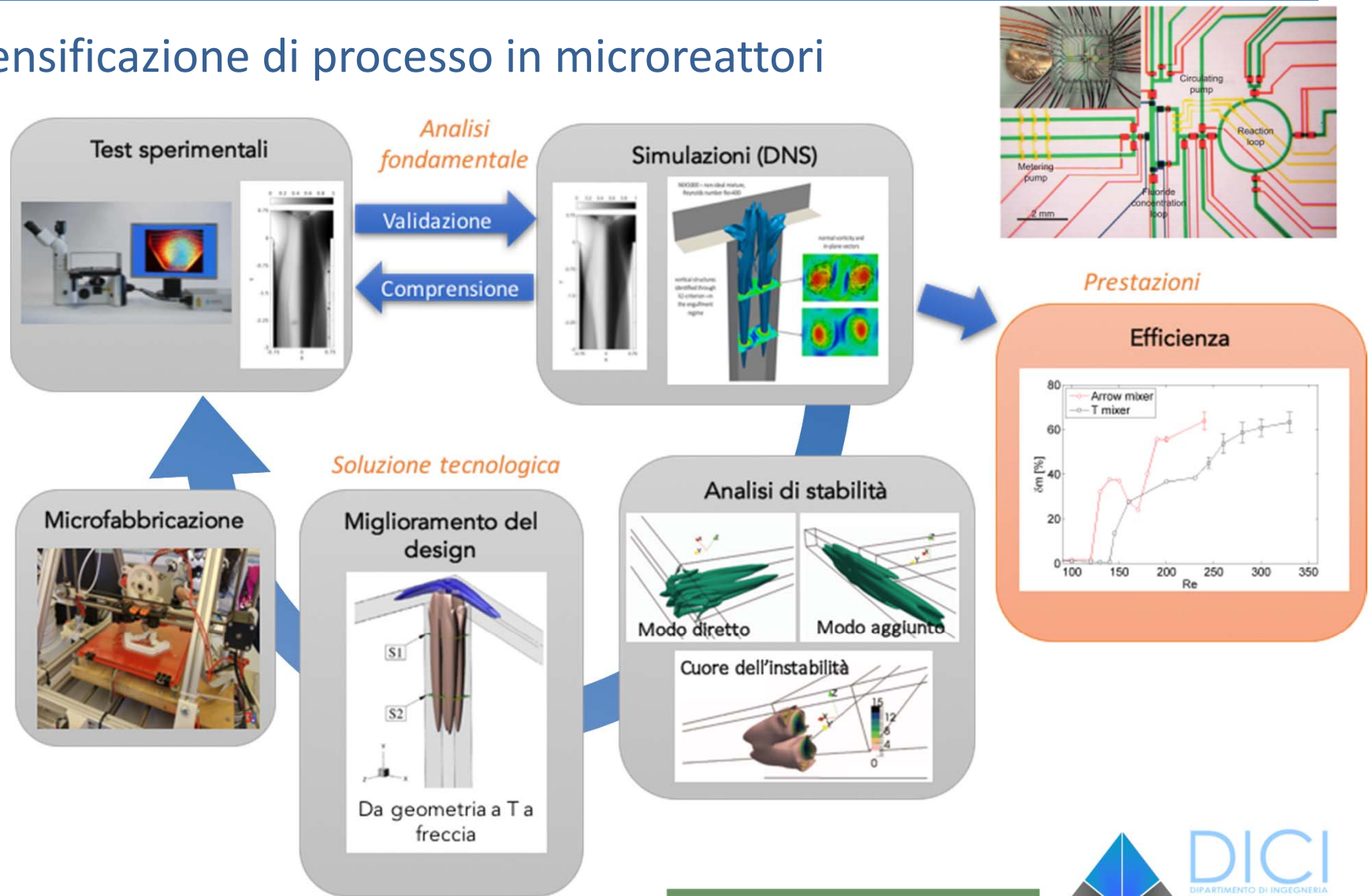


smartphone



SOSTENIBILITA'

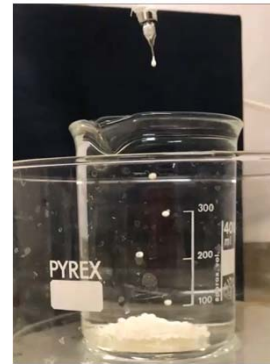
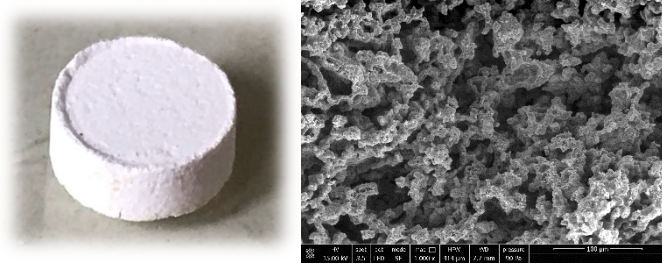
Intensificazione di processo in microreattori



SOSTENIBILITA'

Trattamento effluenti solidi, liquidi, gassosi

CO₂ CAPTURE PROCESS



B **Industrie Bitossi**

DRIP CASTING TECHNOLOGY



HYDROCHAR



Hydrothermal carbonization process

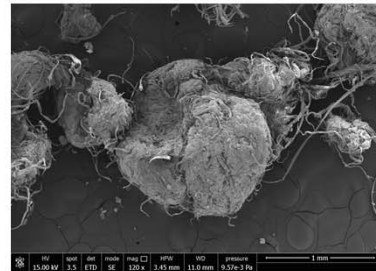
SOSTENIBILITA'

Settore cartario:

proposta LM in Technology of production of paper and cardboard

- Analisi parametrica del processo di confezionamento
- Studio processo di trattamento/riutilizzo fanghi da cartiera

FABIO PERINI
KÄRBER SOLUTIONS



 **LUCART**
GROUP

AIDIC / Associazione Italiana
di Ingegneria Chimica

 **DICI**
DIPARTIMENTO DI INGEGNERIA
CIVILE E INDUSTRIALE
STATI E UNIVERSITÀ
ITALIANE

SOSTENIBILITA'

- ✓ **Progettazione** in ambiente CAD di **impianti di gassificazione/pirolisi** di biomassa ligno-cellulosica su scala commerciale (cogenerazione) e reflui/scarti industriali (fanghi da depurazione, pneumatici esausti);
- ✓ Attività di **pre-commissioning, commissioning e assistenza specialistica** nella realizzazione degli impianti;
- ✓ **Messa a punto**, mediante campagne sperimentali mirate, delle **procedure di start-up, shutdown, conduzione e controllo** degli impianti.

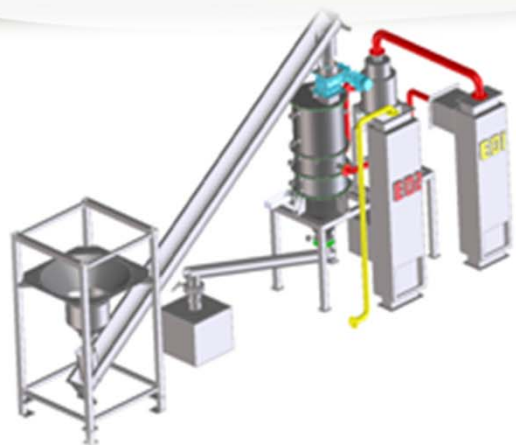
get energy
PRIME ITALIA



glass
SERVICE



enel
Green Power



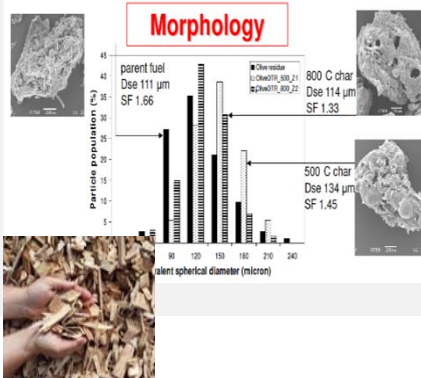
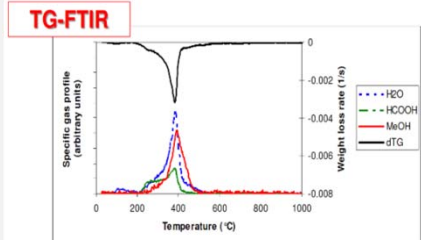
SOSTENIBILITA'

ENERGIA DA BIOMASSE (pirolisi, gassificazione e combustione)

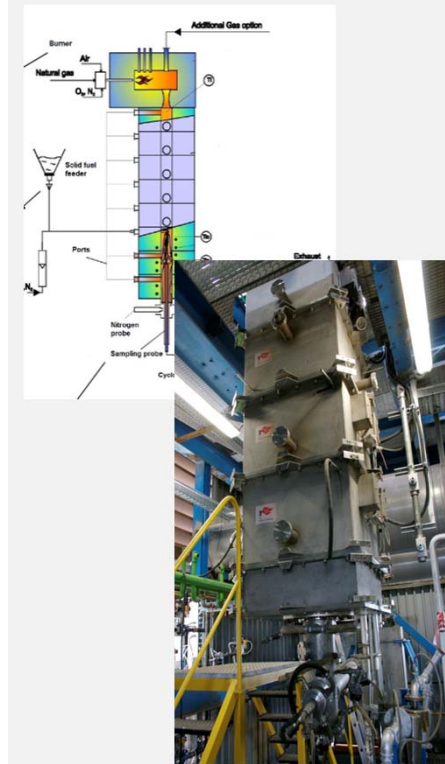
Analisi sperimentale e modellistica



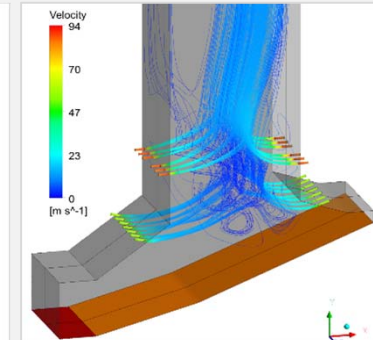
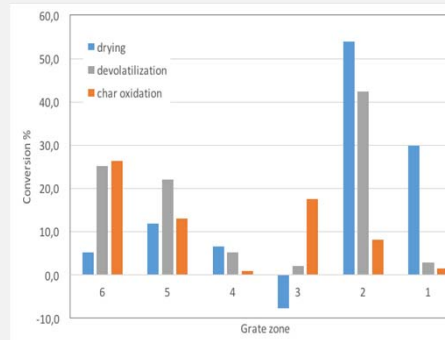
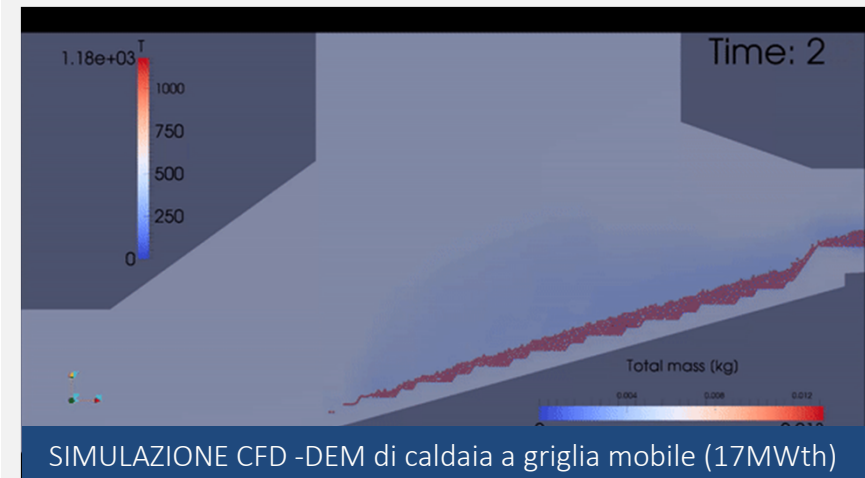
ANALISI LAB



SCALA PILOTA



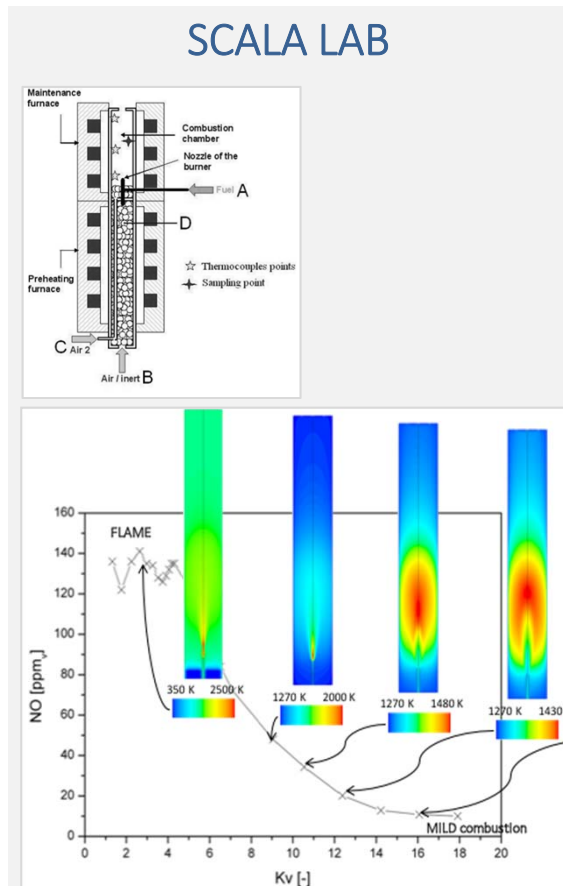
SCALA INDUSTRIALE



SOSTENIBILITA':

Natural gas and hydrogen /syngas for the transition to a decarbonized fuel

- Combustione senza fiamma (MILD): alta efficienza e basse emissioni anche per combustibili 'poveri'
- Analisi sperimentale e modellistica

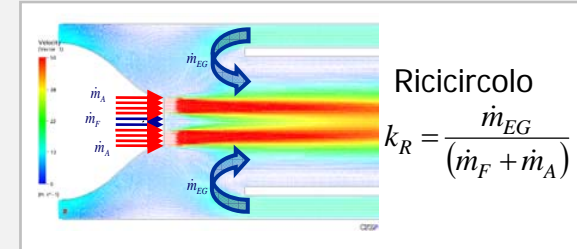


IMMERGAS

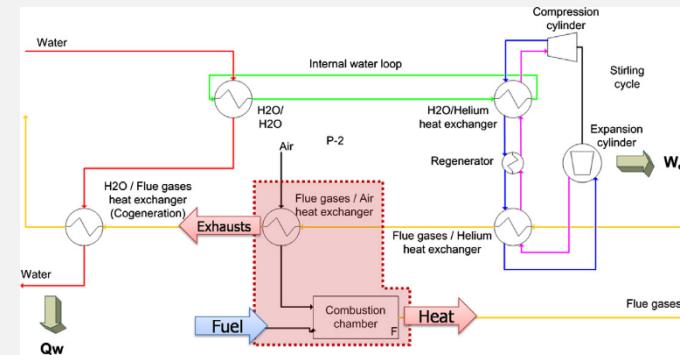
SCALA INDUSTRIALE



Bruciatore autorecuperativo FLOX



Bruciatore Stirling SOLO



Towards overcoming of technical barriers of recovery processes to produce high quality secondary raw materials from lithium-ion batteries

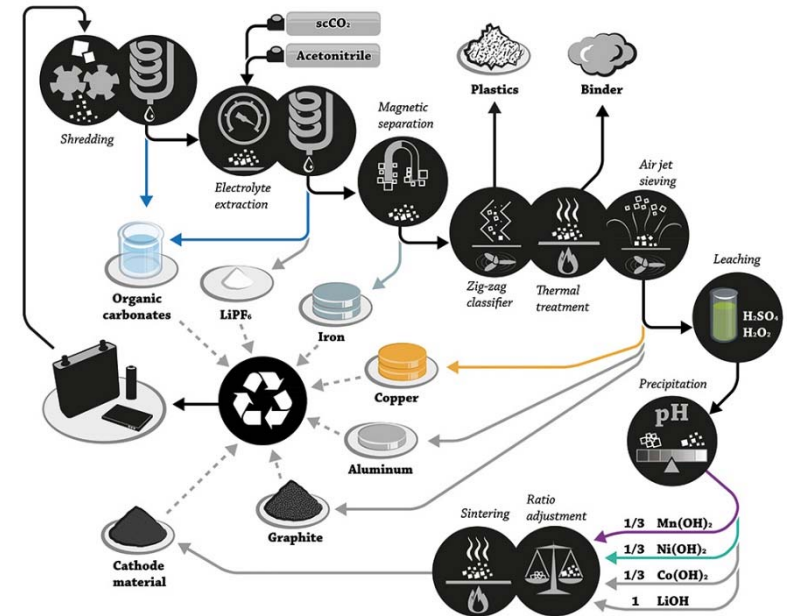
Motivation

- Provide information on **circularity, including secondary raw materials inventories**, stocks and flows
- Support the EU System in the **development of guidelines** (methodological, based on sound techno-economical basis) and quality standards for *secondary raw materials* in order to increase the confidence of operators in the single market;
- Explore the potentials for **technical standardization** of LIB designs and use of the results in other policy applications

How?

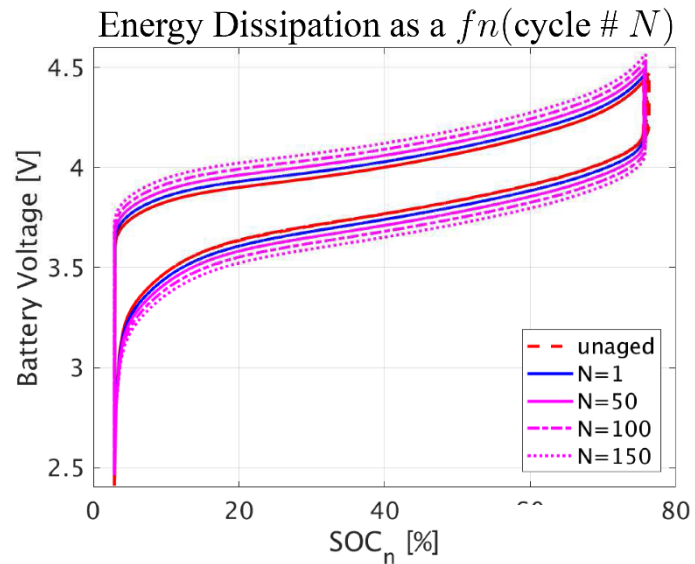
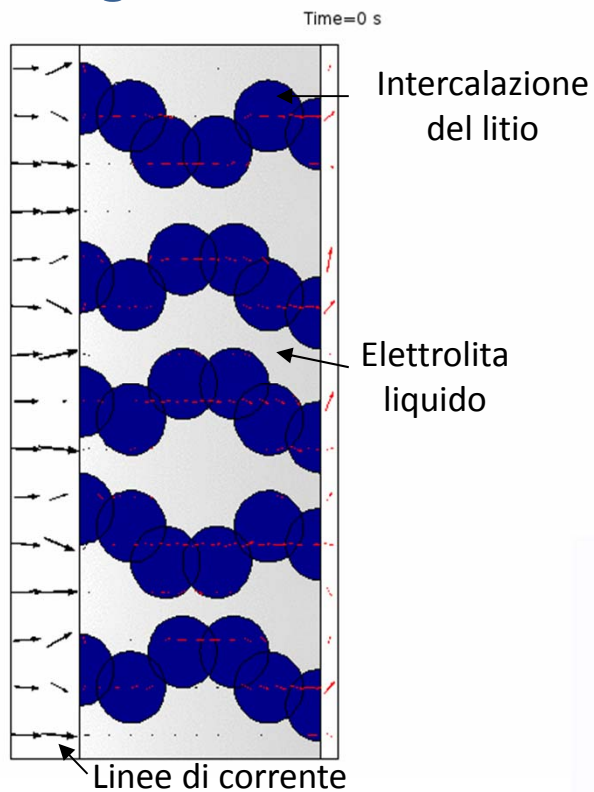
- Literature survey and recovery process/plant definition and preliminary design
- Numerical simulation of the major processes through detailed solution of heat and material balances.)
- Assessment of the environmental impact of the simulated processes by using the LCA methodology

- Partners: produttori di batterie, riciclatori



SOSTENIBILITA'

BATTERIE AL LITIO: analisi dei fenomeni di trasporto di carica e degradazione



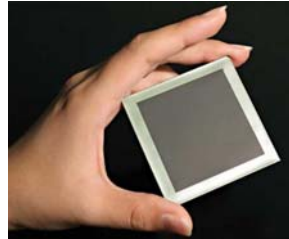
- Analisi effetti di invecchiamento
- Studio condizioni operative per evitare corto-circuiti interni

- Simulazione carica/scarica
- Microstrutture avanzate

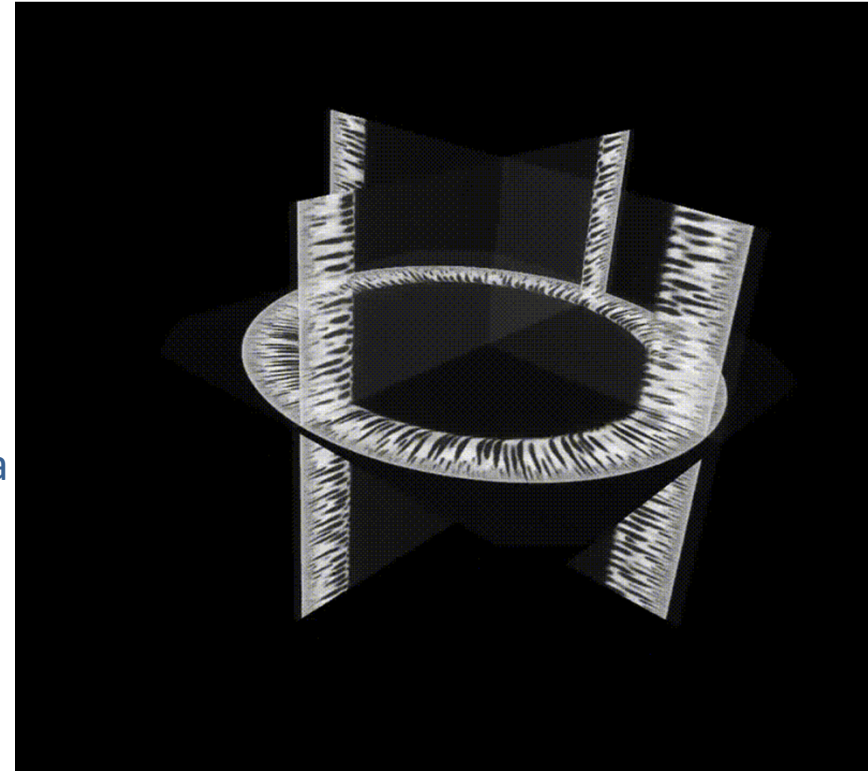
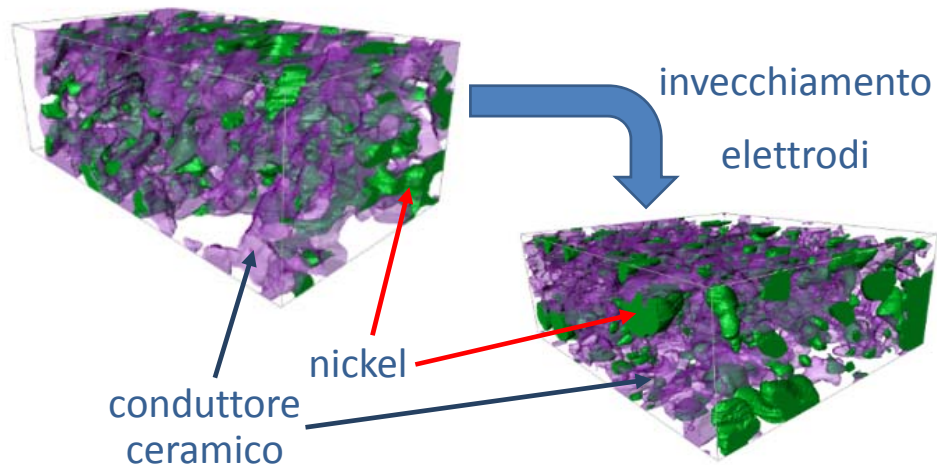


SOSTENIBILITA'

CELLE A COMBUSTIBILE: Simulazione numerica 3D di elettrodi

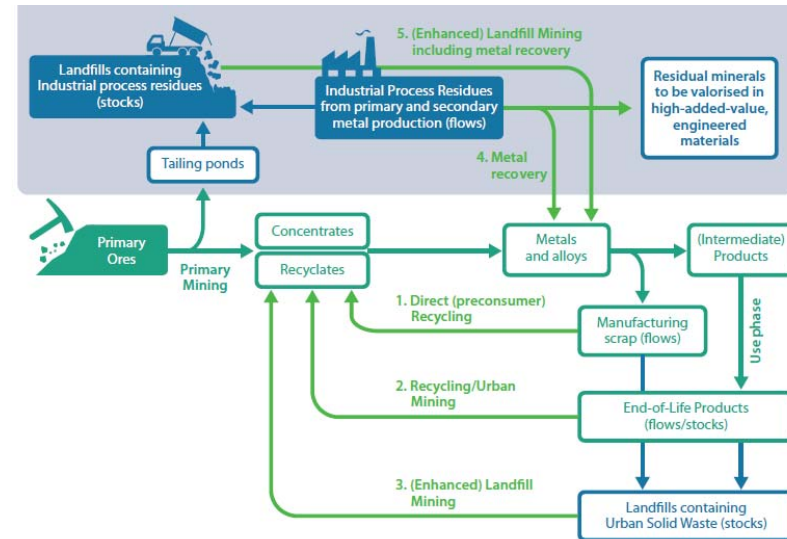


- Modellazione trasferimento di carica
- Ottimizzazione prestazione
- Studio fenomeni di degradazione microscopica



SOSTENIBILITA': Slag process optimization for their Recycle and Reuse

- Motivation
 - Recovery and processing of slag and slag-products coming from steel/metals production cycle
 - Recovery of valuable metals during modification process
 - Recovery of valuable metals from other residues (filtration residues, refractories, etc.)
- How?
 - Material characterization (chemical – Leaching test - SEM- EDX , etc.)
 - Numerical simulation of the slag process
 - **Life Cycle** and risk assessment of different slag process and reuse



- Partners (some)

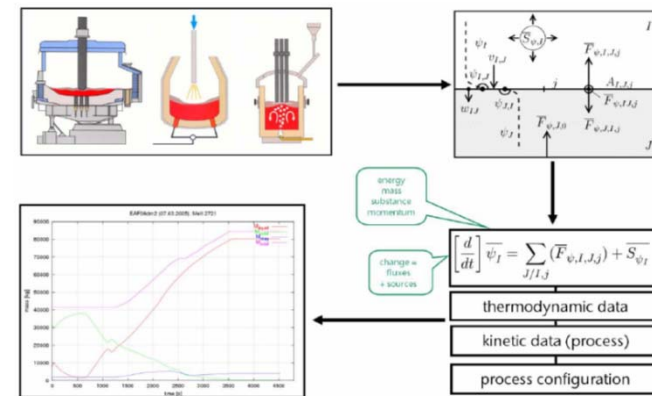
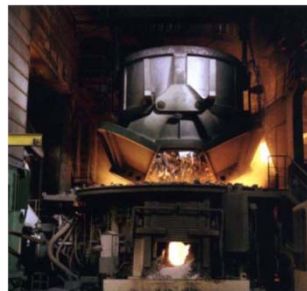
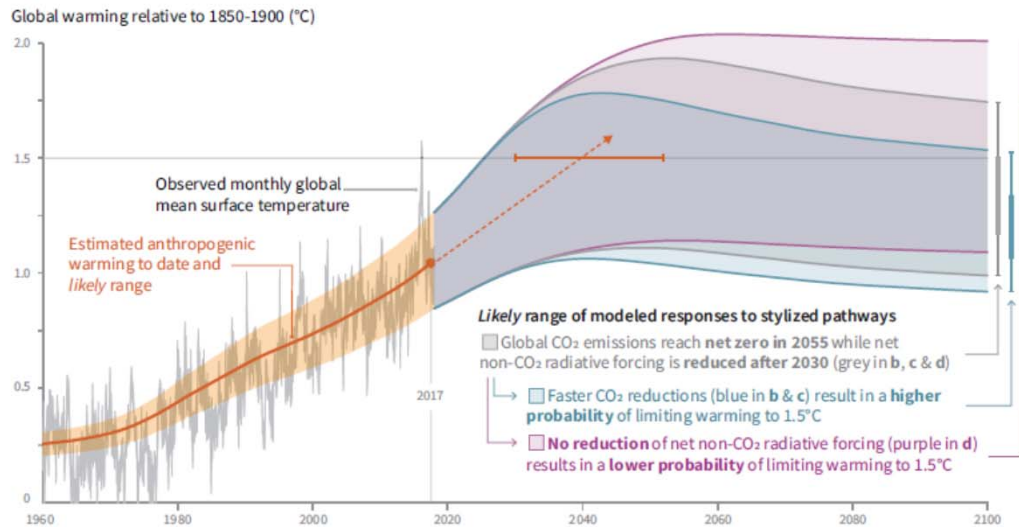


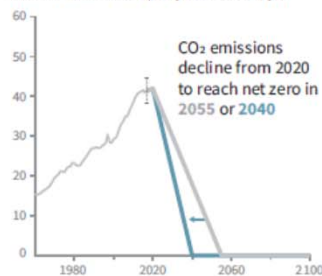
Figure 2: Process Reactor Model concept.

Observed global temperature changes and modeled responses to stylized anthropogenic emission and forcing pathways

a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways

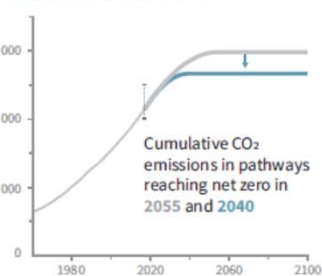


b) Stylized net global CO₂ emission pathways
Billion tonnes CO₂ per year (GtCO₂/yr)



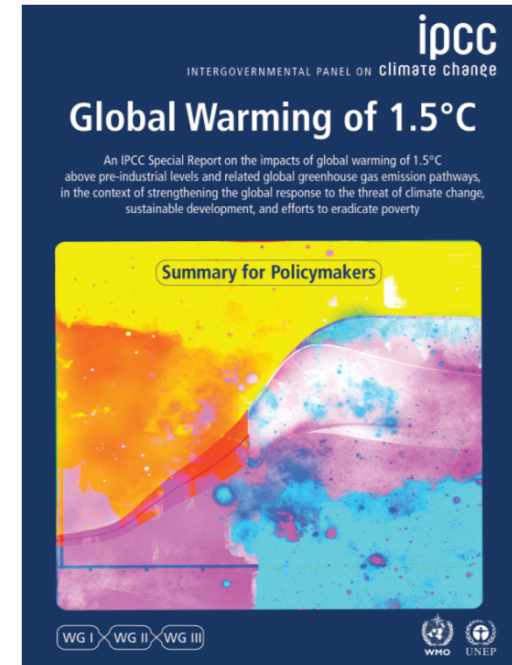
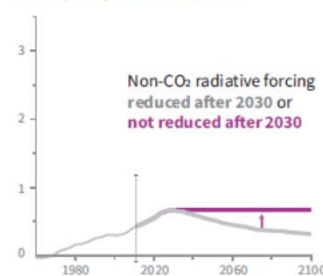
Faster immediate CO₂ emission reductions limit cumulative CO₂ emissions shown in panel (c).

c) Cumulative net CO₂ emissions
Billion tonnes CO₂ (GtCO₂)



Maximum temperature rise is determined by cumulative net CO₂ emissions and net non-CO₂ radiative forcing due to methane, nitrous oxide, aerosols and other anthropogenic forcing agents.

d) Non-CO₂ radiative forcing pathways
Watts per square metre (W/m²)



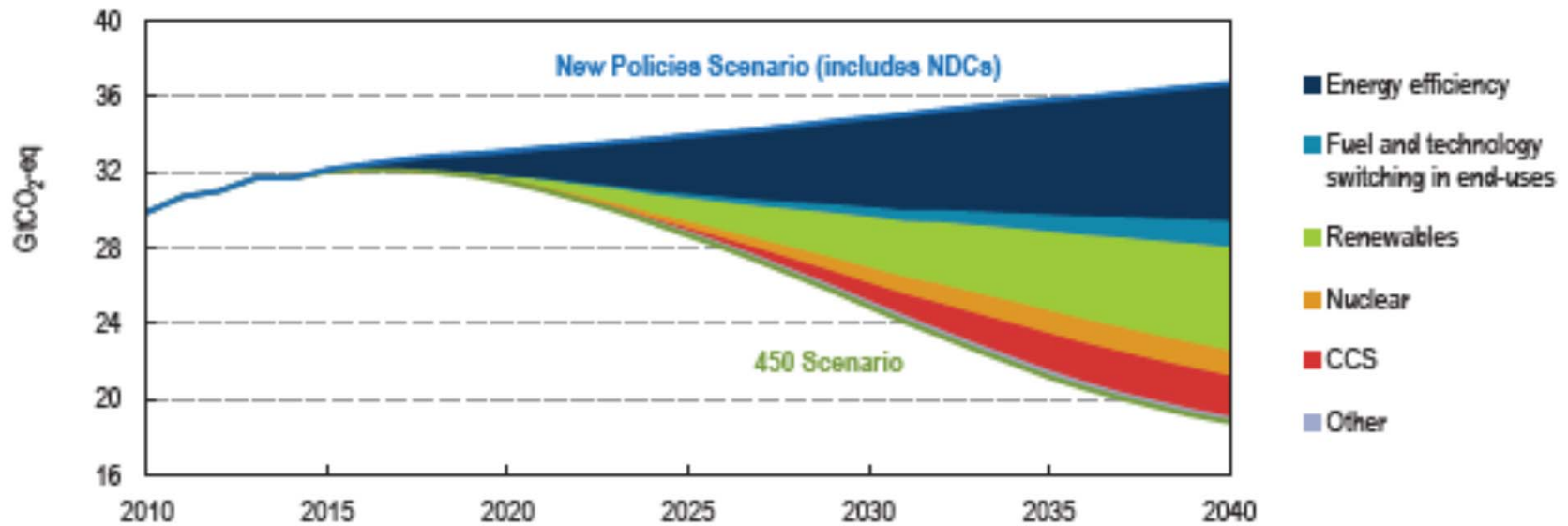
The IPCC was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options.





Measures are needed !

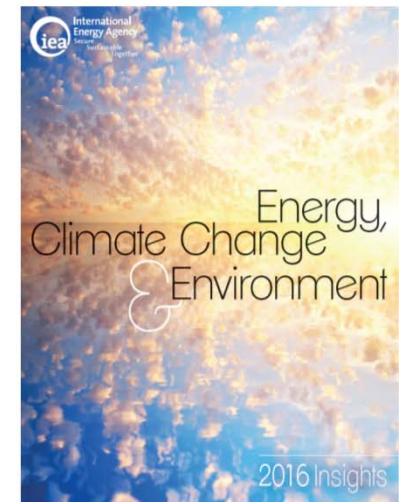
Measures needed to surpass current NDCs to reach 2°C trajectory (450 Scenario), through 2040



Note: The New Policies Scenario (NPS) is the central scenario of the World Energy Outlook and includes the energy-related components of NDCs submitted by 1 October 2015.

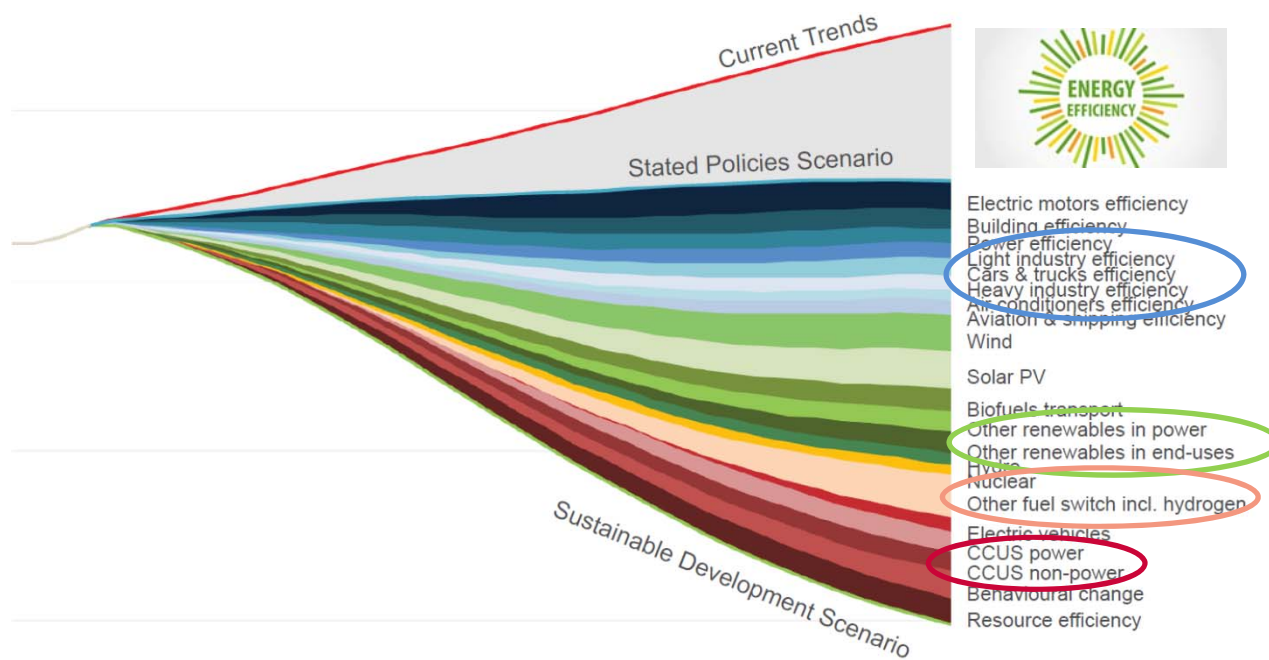
Source: Adapted from IEA (2015b), World Energy Outlook 2015.

Each Party's Intended Nationally Determined Contribution (INDC) submitted for the Paris Agreement will formally become an NDC when each Party ratifies the Agreement. This publication uses the term NDC to refer to both cases (INDC and NDC)



Technologies and Research Topics

The Department of Civil and Industrial Engineering of Pisa University is involved in several projects concerning carbon reduction, the Climate Change and access to energy, in collaboration with Public and Private organisations, and international networks.



Energy-related CO2 emissions and reductions in the Sustainable Development Scenario by source



The research topics at DICI can be summarized as:

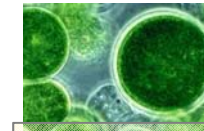
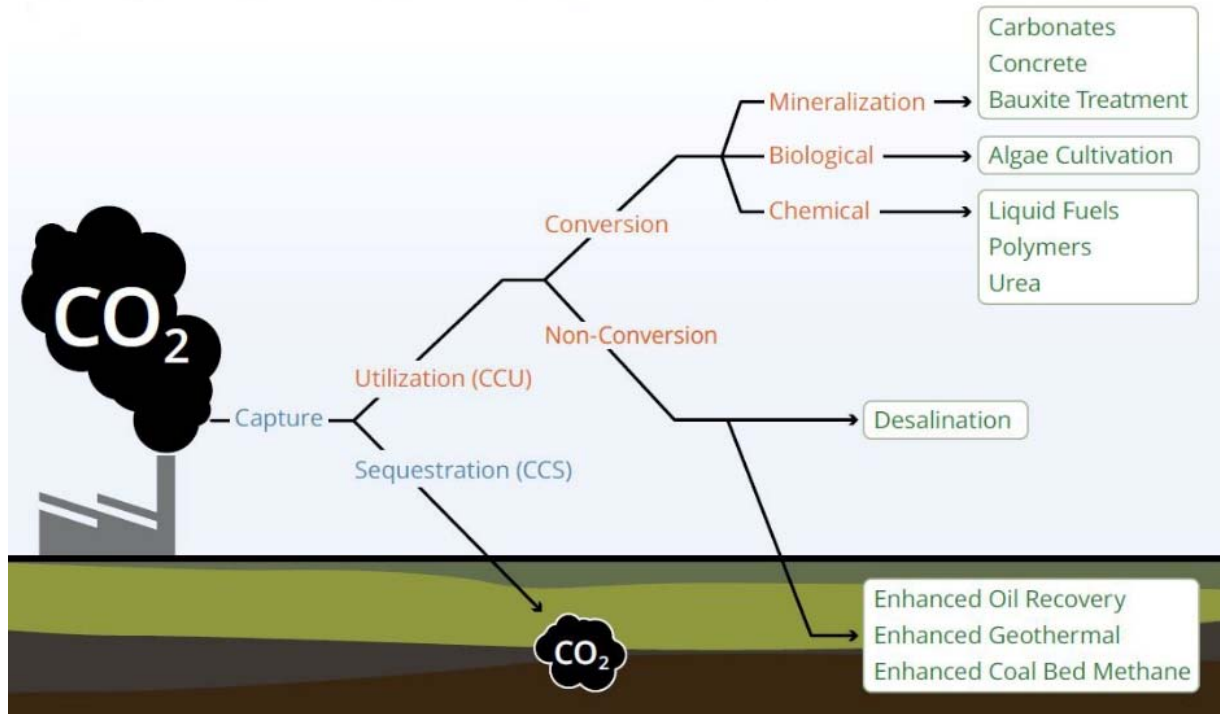
- **Managing emissions from industrial production;**
- **Reducing emissions from power generation: natural gas and renewables;**
- **Carbon capture, use and sequestration**



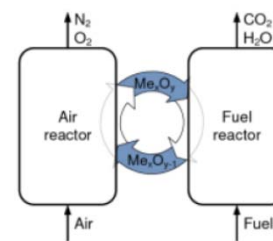
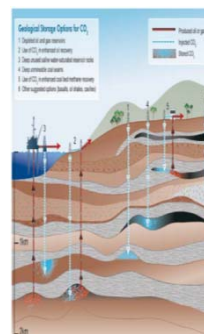
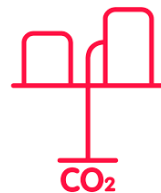
The future: CO2 capture and use



Paving the way — A selection of today's carbon capture and utilization pathways



Algae



CO2 CAPTURE PROCESS



People & partners



- Riccardo Bacci di Capaci
- Federica Barontini
- Antonio Bertei
- Elisabetta Brunazzi
- Patrizia Cinelli
- Beatrice Coltelli
- Chiara Galletti
- Gabriele Landucci
- Andrea Lazzeri
- Roberto Mauri
- Cristiano Nicolella
- Gabriele Pannocchia
- Monica Puccini
- Claudio Scali
- Maurizia Seggiani
- Leonardo Tognotti
- Sandra Vitolo



Consorzio Polo Tecnologico Magona



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