



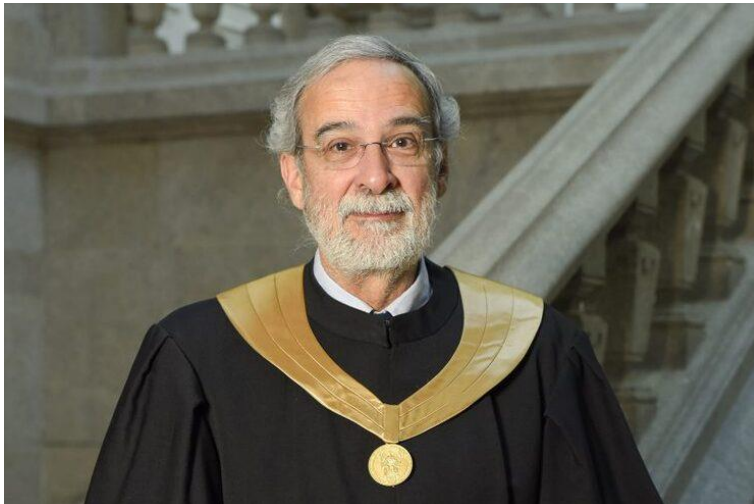
## About the Future of Research in Chemical and Biochemical Engineering

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### A TRIBUTE TO PROFESSOR ANTÓNIO CARDOSO (1955-2022)

A REMARKABLE PROFESSOR OF CIVIL ENGINEERING AND AN EXCELLENT COLLEAGUE



## THE AUDIENCE OF THIS TALK

- I am completely aware that I am speaking to an audience of **World Class Researchers**, that work in a **World Class Department of Chemical, Biochemical...Environment and Materials... Engineering**
- A statement based in facts
  - ✓ Top positions in World Rankings by Subject – Shanghai, QS, NTU...
  - ✓ With high scientific productivity, with a growing number of **Highly Cited Researchers**
- ☞ **SO, I really must 'watch it'!!!**

## TO SAY WHAT I AM GOING TO SAY...

### TWO SETS OF NOTES

- The future of Research and Development in Chemical and Biochemical Engineering
- A vision of public policies, thinking of promoting cooperation with Industry and the necessary valuation of Knowledge

## TWO PAPERS THAT PROVIDE A LOT OF 'FOOD FOR THOUGHT' AND A 'VERY DEAR PAPER' TO ME

- P.R. Westmoreland, Chemical Engineering in the Next 25 Years, Chemical Engineering Progress, 31-42, November 2008
- P.R. Westmoreland and C. McCabe, Revisiting the future of Chemical Engineering, Chemical Engineering Progress, 26-38, October 2018
- M. Von Stosch, R. Oliveira, J. Peres, S. Feyo de Azevedo, [Hybrid semi-parametric modeling in process systems engineering: Past, present and future](#), Computers & Chemical Engineering **60**, 86-101, 2014

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH SETTING THE SCENE

- ☞ How do we expect industry/research to evolve in the next... twenty-five years?
  - Think of developments between the seventies and this century... and between 2008 and today...
- ☞ The role of traditional core areas of ChE expertise, necessarily augmented and in articulation with new expertises...?
- ☞ Education to pave the way and strengthen the research of the future?

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH RELEVANT FIELDS

- ☞ **Energy**
- ☞ **Biotechnologies – namely, but not only, Health related**
- ☞ **Computing and Big Data**
- ☞ **Processing and products – science, manufacturing and sustainability**
- ☞ **Education objectives and approaches**

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH ENERGY

- ☞ **Coal for fuel will keep decreasing(fast)**
- ☞ **Abundant natural gas... BUT**
- ☞ **Point for the emerging renewable energy - price of electricity being generated from solar energy is now lower than that of other forms of electricity generation**
- ☞ **Significant attention to the storage of electric energy**
- ☞ **Future need for electric grids with much greater penetration of cheap renewable (and variable) sources**
- ☞ **Need to look beyond lithium**

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH BIOTECHNOLOGIES – NAMELY, BUT NOT ONLY, HEALTH RELATED

- ☞ **Major progress over the past 12 years**
  - **CRISPR/Cas9/Cas12 tools for gene editing**
  - **Affordable, practical gene analyses**
  - **Data science and informatics**
- ☞ **Hybrid modelling and approaches – First-principles and mechanism-based thinking + Statistical data mining and other Big Data approaches**
- ☞ **Future – Synthetic biology (?) + improved modelling of systems biology and systems pharmacology**

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH COMPUTING AND BIG DATA

- ☞ **In 1973, Slide Rule, no pocket calculators!**
- ☞ **XXI Century – Artificial Intelligence, an emerging practical tool**
- ☞ **Data Analytics – dramatic impact on many aspects of Chemical Engineering – material discovery, process design, process operations, supply chain management**
- ☞ **Process monitoring – Sensors, namely Software Sensors**
- ☞ **Computational science already plays a major role in CE**

## A FEW BRIEF NOTES ON SUBSTANCE FOR RESEARCH

### PROCESSING AND PRODUCTS – SCIENCE, MANUFACTURING, SUSTAINABILITY

- ☞ **Process Sciences and Engineering – the Heart of Chemical Engineering, with the traditional building blocks for the profession**
- ☞ **Process+Product co-design**
- ☞ **Technology intensified processes**
- ☞ **Analytics and Machine-Learning**
- ☞ **Sustainability – Social + Environmental + Financial Impacts**

## EDUCATION OBJECTIVES AND APPROACHES

- ☞ **The Reference Text of the Working Party on Education, European Federation of Chemical Engineering –**
  - **[EFCE Bologna Recommendations 2020](#)**
    - **Fundamentals are all relevant in a different paradigma that includes specialization –**
      - **Interdisciplinarity with other disciplines**
      - **Systems Biology**
      - **Analytics and Machine Learning; Nano Engineering; Sustainability; Ethics; Entrepreneurship; Globalization; 3-D printing....**

## PUBLIC POLICIES TO PROMOTE VALUATION OF KNOWLEDGE (I)

- ☞ Science is quite clearly key to the Salvation of Humanity
- ☞ Scientific development of a Country is totally related to its competitive capacity in this Global World, as it is closely related to the well being of its people
- ☞ Portugal must clearly increase its budget to promote and support research –
  - This necessary increase of investment is clearly linked, for social, economic and political reasons, to the necessary **promotion of valuation of knowledge**
  - Cooperation with Industry, with the productive market of tradable goods, is absolutely necessary
  - Public Policies with multiple complementary strands must be put in place to achieve such goals

## PUBLIC POLICIES TO PROMOTE VALUATION OF KNOWLEDGE (II)

- ☞ Multiple policies
  - On top – increase the number of PhD professionals working in industry with the necessary financial incentives
  - Finance doctoral programmes in very close cooperation with companies – the case study of EnglQ - Doctoral Programme in Refining, Petrochemical and Chemical Engineering
  - Finance research projects in cooperation with Industry, focussing in industrial problems
  - Promote entrepreneurship – support Science and Technology Parks and other institutions to support Startups
  - **GLOBALLY – Bring scientists into the market**

## ACKNOWLEDGEMENTS

**To my Colleagues and Students of the Department of Chemical Engineering**

**For what I learned from them about chemical engineering and life**



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Laboratory for Process Engineering,  
Environment, Biotechnology and Energy



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