DISCURSO PRONUNCIADO POR EL NUEVO DOCTOR DONALD S. SCOTT

Excmo. Sr. Rector Magnífico
Excmas. e Ilmas. autoridades
Miembros del Claustro Universitario
Señoras y señores

I MUST begin by expressing my most profound gratitude to the University of Zaragoza for bestowing on me this prestiguous award, and for the recognition it represents of the accomplishments of the many people with whom I have had the privilege of working. Especially it has meaning for me as a professor from the very young University of Waterloo, that is still building its reputation in research and teaching, to receive this recognition from such an ancient and established institution of learning and research as this University.

Over the past 15 years, I have had many links and many collaborations with valued colleagues and friends in Spain, not only in Zaragoza, but in other centres as well. My wife and I have greatly enjoyed our many visits to Spain, and count these among the best memories of our travels. Especially we will always remember the friendliness and generosity of our Spanish hosts, and their contributions to our joint work. Let me tell you a little of the reasons for these visits, and of the nature of our collaborative efforts.

At the start of my career as a chemical engineer, I spent a year in the Arctic oil fields, and then a years as a research engineer in a fermentation pilot plant. This experience convinced me that I wished to make a career in research, so I took my Doctorate at the University of Illinois. For the next nearly thirty years, I pursued a career as an academic chemical engineering proffesor, at the University of British Columbia and at Waterloo. My research was involved with «clasical» chemical engineering—unit operations of fluid flow and mass transfer, reaction kinetics, mixed gas-liquid flow, etc. This work was all quite fundamental, and most of it seemed to have little direct applied usefulness.

About 25 years ago, it seemed to me, as an engineer, that it would be more interesting to become involved in the study and development of a process, one that might have more immediate usefulness, or be of potential commercial value. I had introduced a course at the University of Waterloo called «Entrepreneurship for Engineers,» and lectured in meetings in Canada and the United States on the need for academic enineers to take their findings to the marketplace, and to try to have their new information put to practical use. I even wrote a book for my students *The Technical Entrepreneur!* So it may have been that I thought it was time or me to see if I could practise what I preached. After some though, it was clear that an abundant supply of reasonably priced energy would be a necessity for both developed and developing countries in the coming decades. The world's store of fossil fuels could not last forever, and many countries had very limited amounts, if any, of such fuels. (Spain, Italy, and the Scandinavian countries coud be examples.) Apart from geothermal energy, which is low-grade and inefficient, and nuclear energy, where further development has been put on hold until adequate and enforcable regulations are in place for its use and control, our sole source of energy is the sun. Oil, coal and gas are, of course, a stored form of the sun's energy. If such fuel as this is not available, we must find means of using the sun's energy directly. Such technology also has the advantage of being renewable and non-polluting.

In recent decades, many renewable energy technologies have been developed or proposed, such as solar cells, solar panels, wind energy, wave action, and the use of biomass. Most of the «have-not» countries, particularly in Europe, have promoted research and development of renewable energy in many ways. Spain was notable in this respect. In Canada, a country in which manufacture of forest products is a majore economic factor, and sunshine is not in very good

supply for 6 months of the year, it appeared that utilization of waste forest biomass for energy purposes might be the most promising and useful avenue to explore. In the late 1970's, Australian scientists had shown that if coal particles were heated for a very short time at high temperature, much more oil could be distilled from this material than was obtained with the conventional coking technology. If this approach could be used for biomass particles, it was not then established what results could be obtained by this method that we now call «fast pyrolysis.» Pyrolysis can be defined as the thermal decomposition of an organic material in the absence of air or oxygen. It is a very ancient process, usually requiring many days, that has been pract sed for thousands of years to produce charcoal, and in the 1800's also used to produce a liquid distillate in low yields that became the first commercial source of many of our common organic chemicals.

To develop a «fast pyrolysis» process for biomass, initially wood particles, operating on a laboratory bench scale, we had to overcome many problem —feeding biomass particles continuously at rates less than 100 grams/hour, fast heating of these particles to high temperatures, quantitative recovery of the products, and analyses of their composition. From 1980 to 1985, all of these problems were overcome in our laboratory through the work of many graduate students, visiting scientists, and he dedicated work of my three research associates—Piotr Majerski, Jan Piskorz, and Dr. Desmond Radlein. These three formed one of the most creative research teams with which I have ever been associated. We achieved many interesting results—woody biomass could be made to give a liquid yield of 70% to 80%, much higher than was ever expected. The liquid product, now called «bio-oil,» was very different from a normal crude oil—it was a fascinating mixture of oxygenated organic compounds, both aliphatic and aromatic, containing about 20% water, and was reactive in many ways. Significant yields of hydroxyacetaldehyde, a very reactive bifunctional chemical with many potential uses could be obtained at the right conditions. It could be burned in conventional oil burners or in stationary diesel engines, with only minor modifications, to give a satisfactory alternative fuel, which could be more easily shipped and stored than biomass.

Subsequently, we found that after pretreating the biomass, mainly to remove its mineral content of potassium and calcium, on fast pyrolysis a liquid product of completely different composition was obtained, one high in

sugars, potentially a base for alcohol production. By-products of all these fast pyrolysis processes are a reactive charcoal and a gas of medium calorific value.

In the 1980's, the European Union was actively promoting development of the technology to utilize biomass as an energy source. In the late 1980's we were approached by a Spanish company, Unión Fenosa, and asked to participate in the design and operation of a small demonstration plant to convert biomass to an alternative fuel oil, using the type of process we had developed. Thus began my long acquaitance with Spain, and the growth of my admiration for the dedication and competence of Spanish engineers and scientists.

The pilot plant was constructed near Santiago de Compostela, and was operated by Unión Fenosa under the project leader, Ángel Cuevas, for over 6 years. It supplied researchers in the European Union with sizable quantities of bio-oil for their own studies on its properties and uses.

About this time, we also became interested in the modification of the process which allowed gasification of the biomass. Bio-gas is a clean and easily burned fuel, ideal for co-generation plants for electricity, although it must be used on site as it is produced. This gasification work was initiated in our laboratory in collaboration with visiting scientists from the University of Zaragoza, notably Professor Jesús Arauzo. Over the past decade, a group at the University of Zaragoza, led by Professor Rafael Bilbao, has extensively studied the fast pyrolysis of biomass using catalysts to obtain high yields of good quality gas. This work has also led recently to the establishment of larger scale pilot plants.

Where does all this development of biomass as a significant energy source stand today? In addition to the investigations at the University of Zaragoza, which cover many more aspects of biomass utilization than only gasification studies, there are also active research groups at the Universities of Alicante, Madrid and Santiago, as well as at government research and development centres, that are involved in both fundamental and applied studies. The use of a wide range of forest, agricultural and urban wastes as pyrolysis feedstocks has been investigated. Also, we known how best to make use of the bio-oil, bio-gas, and charcoal products, as well as how to vary the system operating conditions to obtain optimal results. For bio-oil production, a second generation, much improved process has been developed by the company set up in Waterloo, Canada, by my research associates, and this process has been piloted very suc-

cessfully on a rather large scale by another Canadian company. In addition to the work in Spain and in Canada, active development is also underway in Finland, the United Kingdom, the Netherlands, Italy, Greece, and Portugal.

The day is rapidily approaching when a small increase in the price of crude oil will create economic conditions favourable for the utilization of alternative energy sources, and biomass a fuel will then be a major factor. When that day comes, as I am sure it will in the near future, Spanish institutions and their scientists and engineers will be fully ready to take a leading role.

In conclusion, I must say that the bestowal of this great honour on me by the University of Zaragoza is in reality the recognition of the talents and kills of many people undergraduate and graduate students, research associates, visiting scientists who worked in our laboratories, and the other resarchers around the world with whom we have had so many valuable consultations and from whom we have received so much encouragement. Nearly all progress in science and engineering is evolutionary—we build on the work of others. It is great satisfaction to be recognized for our part in adding some forward steps to our knowledge in the field of alternative clean energy—a necessity for our world in the coming generations.

Muchas gracias.

Donald S. Scott