Preface

Whoever is right—Tad Patzek in pointing out that massive biofuel production will cause ecological devastation, or Shell in claiming that its new fields of *Jathropa* trees will not impact food production—it is impossible to ignore the immense quantities of glycerol resulting from biodiesel manufacture. The volumes of glycerol remaining unsold up to mid-2005 certainly paint a tragic picture of wasted energy and material resources, to say nothing of human intelligence and effort, brought about by the lack of suitable conversion processes for what is the oldest organic molecule known to man. We have even witnessed biodiesel producers experimenting by adding glycerol to animal feed, or spraying it on dirt roads to keep the dust down—and even using it as landfill, as though glycerol were spent nuclear fuel!

Following three or four years of intense research activity, chemical ingenuity worldwide has opened up a number of practical avenues for converting glycerol into value-added products. Many of these are potentially large volume outlets, and may incidentally go some way towards improving the tarnished public image of chemistry. In reviewing and commenting on these achievements this book aims to remind chemical industry professionals, both managers and technologists, of the enormous potential of glycerol as a versatile feedstock for the production of a whole range of chemicals, polymers and fuels. In the ten chapters which follow, readers will find a thorough discussion of new uses for glycerol as a raw material, many of which are already having their impact worldwide.

For example, during the devastation brought about by hurricane Katrina in 2005 the New Orleans petrochemical refineries were shut down, interrupting the supply of a variety of chemicals, including

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By Mario Pagliaro and Michele Rossi

ethylene and propylene glycols. This led a global manufacturer of cement additives to replace these glycols with crude glycerol from biodiesel refineries (Chapter 3). Again, in 2007 Solvay started its retrofitted plant in Tauvaux, France, where instead of making glycerol from epichlorohydrin as had been done for decades, it began to produce this epoxy resin precursor using glycerol supplied by a French biodiesel producer (Chapter 4). Thirdly, by the time this book is published the world's first plant for the manufacture of propylene glycol from glycerol will be in full production in Atlanta, USA (Chapter 5).

This monograph tells a chemical success story, the conversion of glycerol into value-added products, and it identifies the factors which have brought this about. Whether as a solvent, antifreeze or detergent, or as a monomer for textiles or drugs, new catalytic conversions have been developed for glycerol in the synthesis of products with applications ranging from everyday household items to the manufacture of fine chemicals.

Readers will see the ways in which a number of practical limitations posed by the chemistry of glycerol, such as the low selectivity of traditional catalytic conversions, have been solved by a better understanding of its fundamental chemistry and the application of catalysis technology. In addition they will find in Chapter 10 a discussion of the sustainability issues associated with bioglycerol production. The authors are convinced that chemists and chemical engineers must be in a position to present the ''triple bottom line'' dimensions—societal, environmental and economic—to the community, the media and to the business world. Indeed, it is an undue emphasis on sustainability on its own which has often led to controversy such as that mentioned above. It has to be accepted that both politicians and ordinary citizens are *interested* in the arguments for biodiesel and glycerol production, and in turn they want to be reassured that refineries are necessary and environmentally sound. To paraphrase Ozin, emerging biomass-based companies and research centers need young, wise, educated scientists capable of crossing the boundaries between fields and who can explain simply the advantages and problems.

Chemical research on glycerol has shown that, given a strong economic incentive, chemists can rapidly devise a whole set of upgraded processes for biorefineries, and that the integration of these in producing energy and chemicals is not just a romantic dream promoted by green-minded scientists, but an inescapable reality.

Will the biorefinery of the future make use of other platform chemicals apart from glycerol? We have no doubt about it. In 2007, one of us had the good fortune to review University of Peking's Yuan Kou's

paper on direct production of fuels from wood lignin. As we write, this seminal work is undergoing further peer-review after in-depth evaluation by editors and referees of *Science* and *Angewandte Chemie*. Yet, besides known problems with scientific publishing, enormous volumes of lignin, a by-product of cellulose manufacture, are burned in power stations, a low quality outlet parallel to that sought for many years for surplus glycerol. In one sense it could be claimed that the low price of oil in the 1990s ($10 to $20 a barrel) applied a dampener on chemical ingenuity for the whole decade, since many developments were put on the shelf until a day in the future when their use would become ''economically viable''. Today, not only has the price of oil multiplied by a factor of 10, but the concept of energy return on energy invested (EROI) shows that in the USA domestic petroleum now returns as little as 15 Joules for every Joule invested—whereas in the 1930s the figure was 100 Joules (C. Cleveland *et al., Science*, **2006**, *312*, 1746). It is exactly this decreasing trend that is forcing society globally to switch from fossil to renewable fuels, until the day when cheap and abundant solar energy becomes a reality. In this evolutionary period biofuels—and biodiesel in particular—will certainly play a role, and it inevitably follows that glycerol will remain a key raw material for many years to come. For example, following the Dumesic findings (Chapter 2) we can readily envisage a time when syngas obtained in high yield from glycerol will be used to synthesize both fuels and methanol by the Fisher–Tropsch process.

Finally, it is obvious that the greatest contributions are going to be brought about by today's students, whose creativity will produce spectacular advances. To avoid this monograph rapidly becoming out of date it is our intention that it must remain a ''living'' book, and that readers will have access to periodic updates posted online on the RSC website.

Mario Pagliaro, Michele Rossi
Palermo and Milan