ACTUAL NEEDS AND POSSIBILITIES TO PRODUCING BIO-JET FUEL

Bohdan Naumienko, Grzegorz Rarata
Institute of Aviation

Summary

Since the beginning of the century, various studies, reports and popular scientific papers have investigated the potential for use of biofuels in aviation. In its recent actions EU also perceives the need for he introduction of sustainable biofuels to help reduce dependence on fossil fuels in air transport and reduce GHG emissions by the air industry. Thus, various feedstocks and conversion technologies for production of biofuels for aviation are currently being investigated within EU (SWAFEA, ALFA-BIRD and Clean Sky JTI). The current EU policy states that sustainable bio-jet fuels are the only option that can be delivered over the medium term, in time to make a significant contribution to EU 2050 emission reduction targets [11].

However, it seems that commercial producers of fuels cannot justify investment in a Bio-Jet fuel production facility until guaranteed availability of sustainable feedstock and clear legislation. EU government is currently taking necessary steps to open a long-term option for the aviation biofuel production in the local market and to support its development. Whereas microalgae is certainly a feedstock considered by many future Bio-Jet producers. Only microalgae seems to offer vast potential as a source of aviation biofuels, however on the more distant horizons of an industry, in which long-term time scales are certainty. Besides, microalgae co-products are utilised at making complex organic compounds like B and C vitamins and beta-carotene that are used as fragrances, flavourings, pigments and supplements. Generally, the research done so far have demonstrated that only a portion of the crude algal oil is suitable for making biodiesel fuel, and most of it can be used to produce gasoline and Bio-Jet like fuels.

If we look from the space at Earth in the night, the view of electric lights concentration does not leave any doubt: we live in the world with big and increasing demand for energy.

In European Union which the member is Poland, the use of energy and GHG emission is not dramatic, but still needs some reflection. If we approximate the trend from year 2005, then in year 2030 the energy consumption increases 11% and CO_2 5.4%.

This situation forced the European Commission (EC) to meet the following goals until year 2020, first time as binding for all EU members:

- 20% decrease in GHG emission
- 20% increase in renewable energy sources
- 20% increase in energy efficiency
- 10% increase in biofuel use

Additionally to the problems with increasing demand for energy, EC also sees a matter of supply reliability. After Russia-Ukraine gas dispute in January 2009, it turns out that mitigating of energy crisis depends as usual on source differentiation and as well on monitoring of current energy market, and the Energy Commissioner Andris Piebalgs appealed to European Parliament for complying law regulations with new threat. In meantime, EC itself issued the proposal of a new regulation adopting the old one No.736/96 which should in principle allow monitoring of energy market and investment projects at EU scale.

In the context of these problems, the Polish objective that during the following next 20 years we should provide 15% of energy needs basing one renewable sources (RS), it seems to be hard to achieve. But maybe we can get that 10% of biofuel.

Tab. 1. Polish potential of renewable energy sources (Wiśniewski G., 2006)

Source of energy	Percent of national technical infrastructure	Percent of national use
Biomass	43.1	94.8%
Sun	25.4	0.12%
Wind	16.1	0.17%
Geothermal	12.6	0.29%
Water	2.8	4.62%

Let us see what is the Polish potential of renewable energy sources (Tab. 1).

The table above show clearly that the first resource and its technical potential is biomass. Therefore, from SE^2 reasons (security, ecology, economy) Polish the main interest should be getting started the clean transport industry from production of biofuel with use biomass and the sun energy.

1. CURRENT CLASSIFICATION OF BIOFUELS

There seems to be lack of a clear classification for biofuels. The most important feature of all biofuels is that they are derived from biomass. That means to produce them, sources of carbon, hydrogen, oxygen, nutrients, and sunlight are required. Basically for making biofuels we need glucose, cellulose or oil.

Oil producing plants, like those used in vegetable oils, or algae, can be used much like fossil sources of oil. Oil derived from such sources of biomass is suitable raw material for creating simple biodiesel that can be burned by cars or further processing to synthetic biofuel kerosene like (replacement for petrochemical Jet A or Jet A-1). The latter type of biofuel is the effect of recent technological innovations that have created the fields of advanced bio-fuels, which focus on non-food sources and drinking water sources. So, these kind of biofuels prevents the debate on whether growing crops for fuel will result in fewer available food crops. This new forms of fuels can literally be called green, as they are derived from green algae. Some algae, especially microalgae, species characterize very high oil content. The oil may be processed like other oil from crops, for example via hydrotreatment or other chemical reaction processes that use catalysts. Many developed countries, with USA ahead, are now doing extensive research on algae. Some of them are easy to cultivate and grow extremely quickly, compared to the traditional oil crops. According to some estimates, some algae can produce tens times as much oil as one acre of rape and may utilise municipal sewage as a source of nutrients.

As a matter of fact, there are still many doubts about the future use of biofuels, not only in Poland. A good understanding and strong backing of bioenergy by the wider European public seems to be an essential background for policies supporting the introduction and wider use of biofuels. Thus, a better understanding of the acceptance and public perception of biofuels and resulting strategies to gain higher public support have to be a question of great importance.

Picture below (Fig. 1) presents different kinds of renewable fuels together with the sources of biomass and conversion technologies for their production.

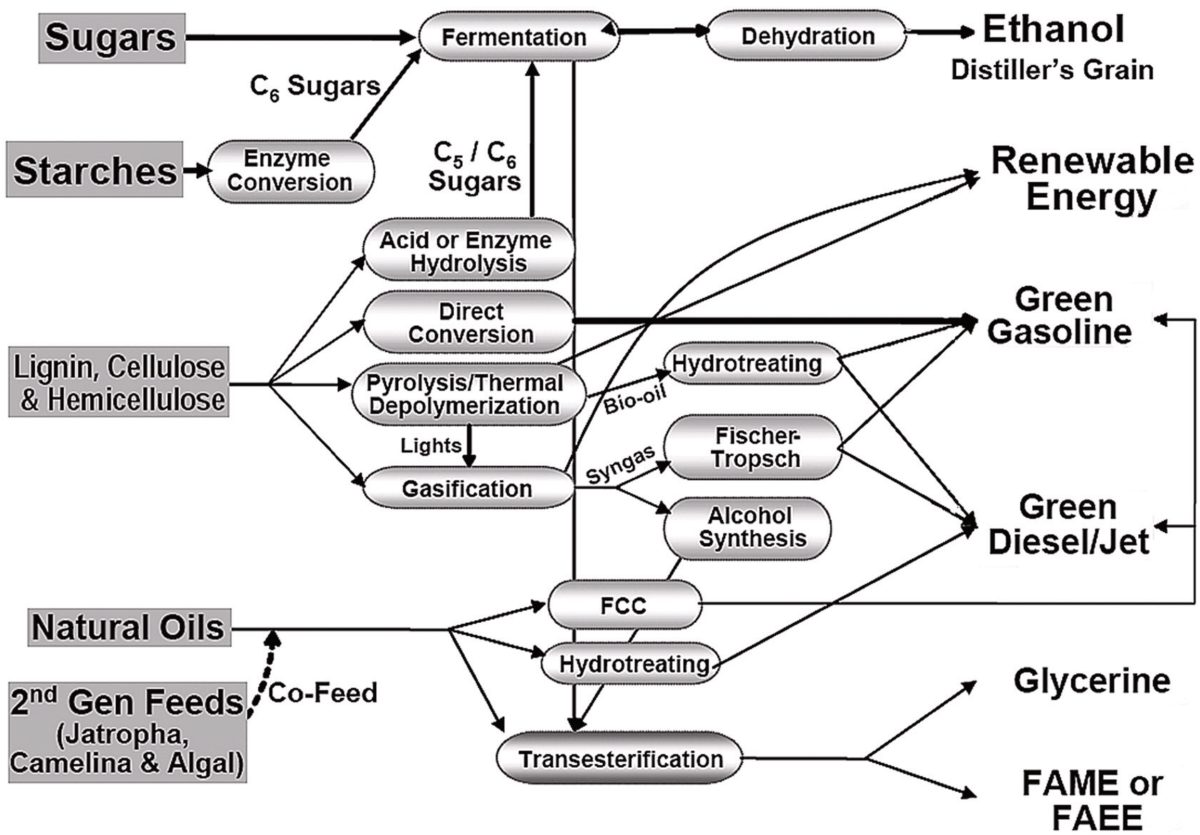

Fig.1. Schematic diagram of current structure of biofuels market [1]

Peering into the future seldom produces a clear picture but nowadays there is a key question about future consumption of biofuels. Currently most research into efficient algal-oil production is being done in the private sector, but predictions from small scale production experiments prove that using algae to produce biodiesel may be the only viable method by which to produce enough automotive and aviation fuel to replace current world usage. Another fact is that the profitability of biofuels production is extremely variable. Due to the volatile price nature of oils, its major feedstocks, biofuels profitability can change rapidly from month to month and member countries of EU, depending also on changeable crude oil prices and legislation.

In fact, the rise in oil prices is the most important factor increasing the competitiveness of alternative fuels, including biofuels. The unprecedented recent rise in oil prices has prolonged opportunities for energy conservation and generated increased supply from alternative fuel sources. While these adjustments may eventually decrease oil prices, most forecasts do not show real prices falling below 50 dollars per barrel. Emerging new technologies of III generation biofuels from microalgae provide a clean, renewable form of energy that would help Poland to find its energy independence. Thus, the most obvious finding so far is that new technologies resulting from research and development are the key to developing a sustainable biofuel industry that meets national targets. These technologies include enhanced production systems (sustainable management tools; better data, models, and decision tools) as well as the integration of feedstock production with conversion and utilisation.

Currently, it is obvious that biofuels from algae could be a meaningful part of the solution in the future, especially taking into account the EU requirements towards year 2020 (that biofuels will account for 10% of European fuel market). These assumption applies also to the aviation industry that will need carbon-neutral biofuels as a feasible way to reduce its reliance on fossil fuels and cut its greenhouse gas emissions. In Europe there have been lack advanced research in this field, compared to the USA.

One reason for this situation may be fact that there is a significant delay in the reliance on advanced alternative fuels in Europe in general (Tab. 2).

Tab. 2 .World leaders in biofuel production [2]

Country	Production (kton, year 2007)	Contribution (%)
USA	13 793	40
Brazil	11 397	33
Germany	2 779	8
China	1 202	3

Bio-derived Synthetic Paraffinic Kerosene (Bio-SPK), made from Jatropha, Camelina, algae or halophyte feedstocks, is so far the most promising candidate in the USA for alternative jet fuel and test flights have successful proven its feasibility as a replacement for conventional jet fuel [3].

2. AVIATION PETROCHEMICAL FUEL (JET)

Today the most commonly used fuels for commercial aviation are petrochemical Jet A and Jet A-1 which are produced to a standardized international specification. There are kerosene grade fuels produced by the most oil refineries around the worlds and are suitable for most turbine engine aircrafts. Only a fraction of this production, in South Africa, comes from coal conversion via CTL process (Coal to Liquids) [4].

Aviation fuels such as the most common aviation fuels utilized by the commercial airline industry – Jet A or Jet A-1 – must satisfy rigorous specifications to operate successfully in flight, including physical properties as well as “fit-for-purpose” operating criteria. Aircraft, for example, operate at temperatures ranging from greater than 55 °C at ground level to less than -60 °C at altitude, and at elevations ranging from ground level up to 12 km. In addition, turbine engine manufacturers are increasingly utilizing the fuel prior to combustion as a hydraulic fluid for actuating advanced engine features. This extraordinarily broad range of operating conditions and functions requires special examination of alternative jet fuel cold flow (viscosity), flash point, distillation, energy density properties, as well as engine system compatibility.

Thus, Certification of jet fuel is a complex, expensive and lengthy process that requires clear technical standards, international cooperation and industry support. The US standards for all fuels are set by the ASTM International organization.

ASTM has recently established a new standard (ASTM D 7566-09) for Aviation Turbine Fuel Containing Synthesized Hydrocarbons [5].

Tab. 3. Estimated oil production from different biomass sources (authors' comparison)

Biomass	**Oil content (liters/hectare)**
Corn	150
Soybeans	400-500
Sunflower	800-1000
Rapeseed	1000-1500
Oil Palm	2400-2500
Microalgae	20000-57000

It is essential that certification policy be technology neutral, requiring physical properties and fit-for-purpose specifications assessed only on final fuel blends as used and not the blending components.

3. BIOMASS DERIVED JET FUEL

There are current research analyses that microalgae are potentially the most promising feedstock for producing large quantities of sustainable aviation biofuel Jet A like. The lipid and fatty acid contents of microalgae vary in accordance with culture conditions and may be as high as 70 to 85% on a dry weight basis [6].

Such high lipid contents, exceed that of most terrestrial oil crops, thus traditional oilseed crops are not the most productive or efficient source of vegetable oil. Micro-algae is, by a factor of 8 to 25 for palm oil, and a factor of 40 to 120 for rapeseed – the highest potential energy yield terrestrial vegetable oil crops (Tab. 3). Additionally, microalgae present multiple possibilities for fuels production – biodiesel, ethanol, methane, jet fuel, biocrude and more – via a wide range of process routes. Each of these process routes presents its own set of opportunities, parameters, dynamics and challenges. Besides, microalgae can be grown quickly in salt water (e.g. in the desert).

Solazyme was one of the first companies in the world that started producing a variety of renewable products from algae oil, including renewable diesel that meets ASTM D975 standard and renewable jet fuel that meets all 11 key tested criteria for ASTM D1655 (the world's first algae-based jet fuel) – the latter one in 2008 [7]. Solazyme's technology is feedstock non-dependent, which allows commercial scale production plants to be placed worldwide, adjacent to many non-food biomass sources and waste streams (Fig. 2).

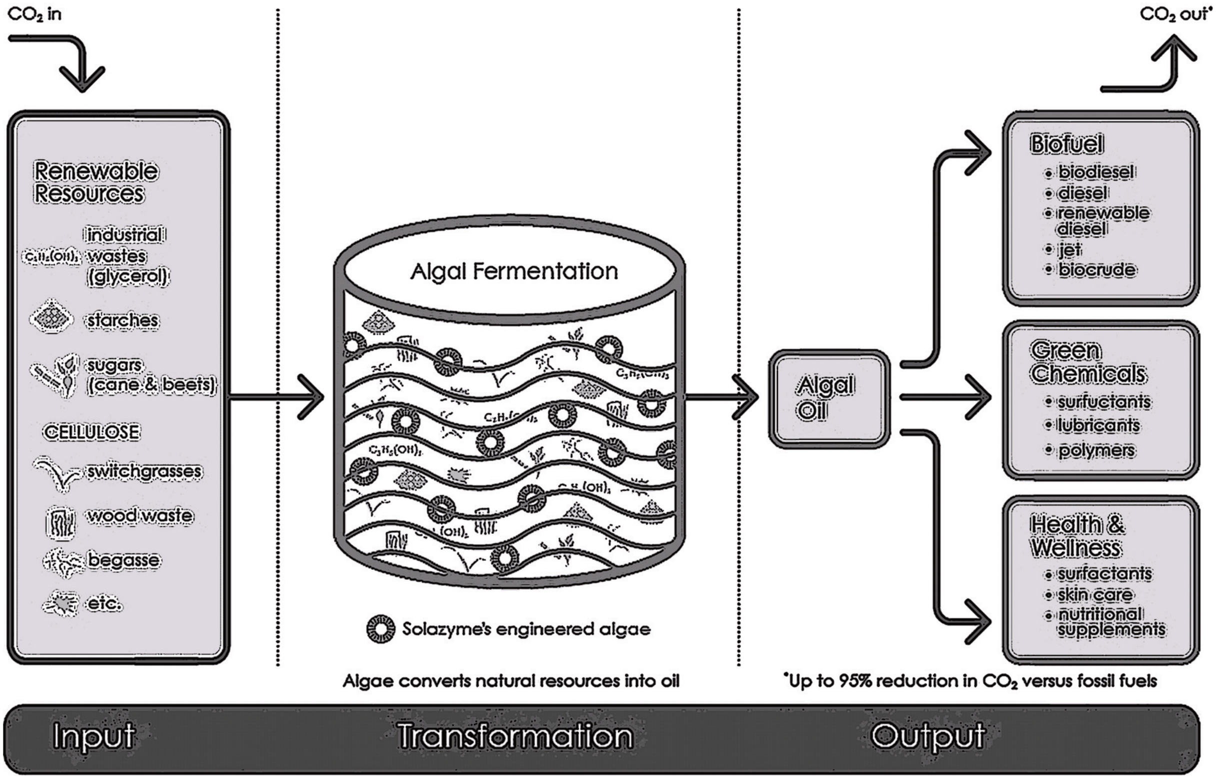

Fig. 2. Scheme of Solazyme technological process [7]

Another private algae fuel company is Sapphire Energy, which has raised more than $100 million from Bill Gates' investment firm Cascade Investment, as well as ARCH Venture Partners, Wellcome Trust and Venrock. Sapphire announced that it will make 1 million gallons of algae-based diesel and jet fuel per year by 2011 and 100 million gallons per year by 2018 [8].

UOP, a Honeywell company, gained contract from DARPA in 2007, for producing renewable jet fuel for military (Synthetic Paraffinic Kerosene, Bio-SPK). UOP LLC, a Honeywell company is a leading international supplier and licensor of process technology, catalyst, adsorbents, equipment and consulting services to petroleum refining, petrochemical, and gas processing industries. UOP technology for the production of clean, high quality fuels and petrochemicals is used today in almost every refinery around the world.

The UOP proprietary process is based on the hydroprocessing technology that has been used in refiners for almost 50 years. Hydrogen is used to remove oxygen from the natural oil and then the product is further isomerized to get to the product properties needed (Fig. 3,4).

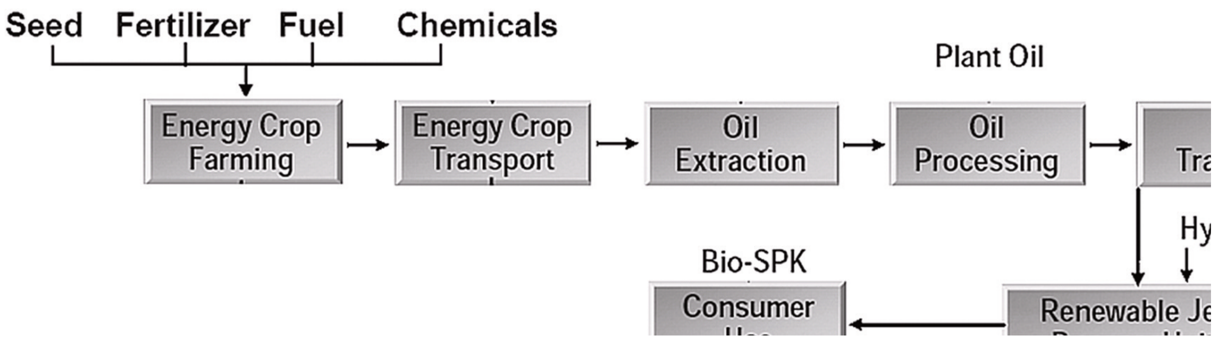

Fig 3. UOP's Hydrotreated Renewable Jet Process [9]

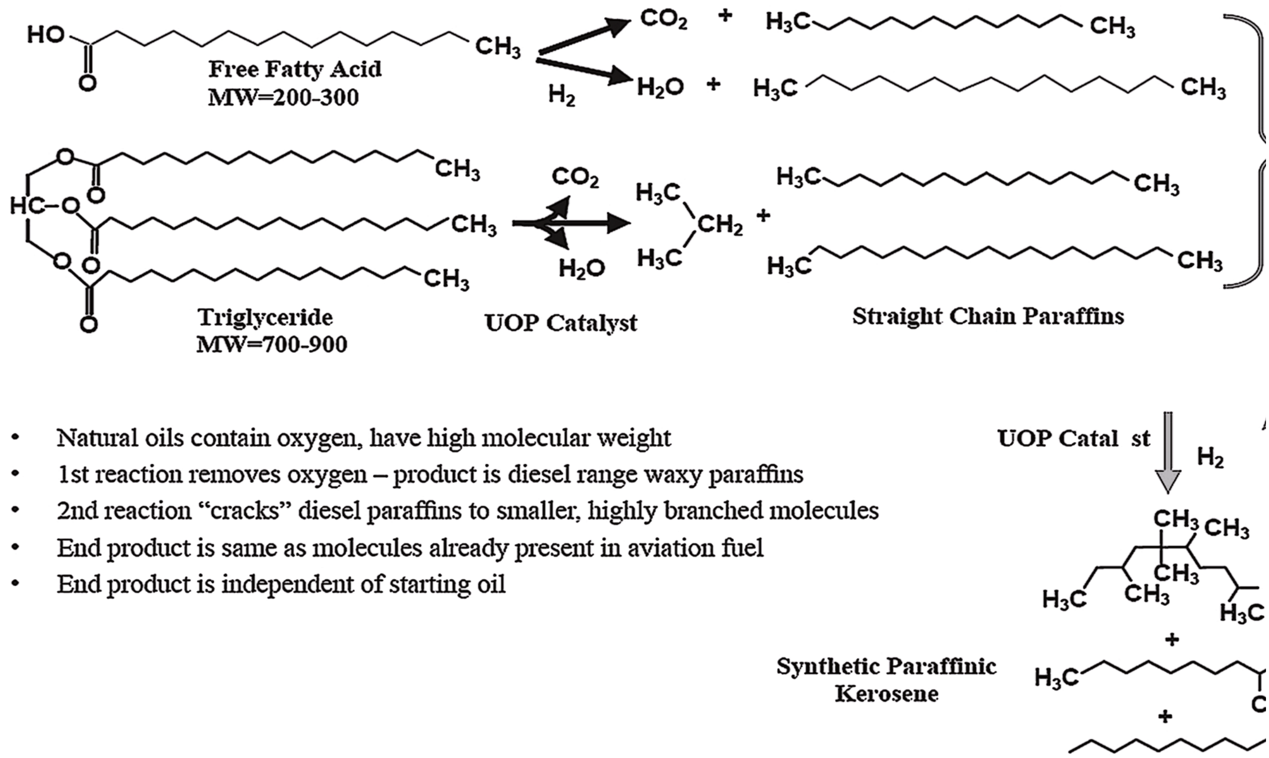

Fig.4. Bio-SPK fuel production process by Honeywell/UOP [9]

Developed using plants such as jatropha, algae and camelina, bio-SPK fuel has been successfully utilized by commercial aircrafts at a blend ratio of up to 50 per cent with traditional jet fuel. Currently tests are going on and various SPK fuels are now waiting for the regulatory approval for use on commercial flights. Additionally, a coalition of companies from across the aviation industry, including Boeing, Continental Airlines, Air New Zealand and Rolls-Royce, have also found that Bio-SPK outperforms traditional petroleum-based aviation fuels.

A study revealed that Bio-SPK delivers a cleaner burn resulting in improved fuel efficiency and less wear on engine components [9].

4. TECHNOLOGICAL BACKGROUND

The renewable jet process compiled by UOP LLC company is a good example of novel technological methods that may be implemented in aviation biofuels production. The process can convert a variety of refined natural oils and fats including edible and non-edible natural oils, tallow and algal oils. The renewable jet process uses a selective cracking step which reduces the natural oil C_{16}-C_{18} carbon chain lengths to carbon chain lengths in the C_{10} to C_{14} range for jet fuel. The renewable jet process is based on UOP’s EcofiningTM process, which is commercially available for the production of green diesel produced from biofeedstocks. While the Ecofining unit can produce up to 15% of Bio-SPK jet fuel, as a co-product with diesel, this new process is designed to maximize the yield of Bio-SPK to 50-70% [10]. This is achieved by optimizing the catalytic processes of deoxygenation, isomerisation and selective cracking of the hydrocarbons present in natural oils and fats to yield a high quality, ultra-low sulphur jet fuel that meets Jet A-1 specifications, including freeze point of -47°C and flash point of 38°C (Fig. 5). Co-products from this new process are diesel and naphtha range material. The process can be adjusted to produce a specific freeze point of the Bio-SPK or can alternately be operated in a diesel mode.

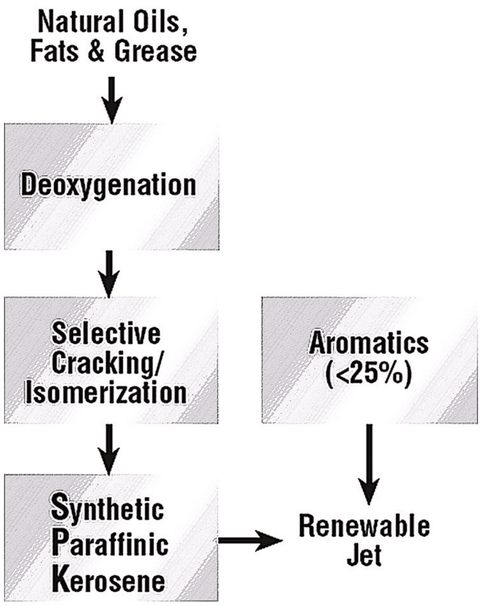

Fig.5. Overview of Renewable Jet Production by OUP LLC [10]

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Streszczenie

W artykule przedstawiono skrót aktualnych osiągnięć technologicznych na temat potencjalnego zastosowania biopaliw w lotnictwie. Zaznaczono również, że ostanie dyrektywy Komisji Europejskiej także faworyzują wprowadzanie biopaliw do transportu lotniczego, celem zmniejszania zależności od importowanych paliw ropopochodnych oraz obniżania emisji gazów cieplarnianych. Wymieniono różne podejścia technologiczne do zagadnienia produkcji biopaliw dla lotnictwa.

Autorzy identyfikują mikroalgi jako najlepszą alternatywę do produkcji biopaliwa lotniczego w dłuższej perspektywie. Podobnie wielu innych producentów biopaliw rozważa taki scenariusz. Biomasa z mikroalg bowiem wydaje się być najbardziej obiecującym źródłem do produkcji bio-zamiennika paliwa Jet A-1, jak również wielu innych, użytecznych związków organicznych. Ponadto, jak wynika z dotychczas prezentowanych badań, jedynie część biomasy z mikroalg jest użyteczna dla produkcji paliwa typu biodiesel, znacznie więcej zaś może zostać wykorzystane do produkcji benzyn oraz paliwa typu Bio-Jet.