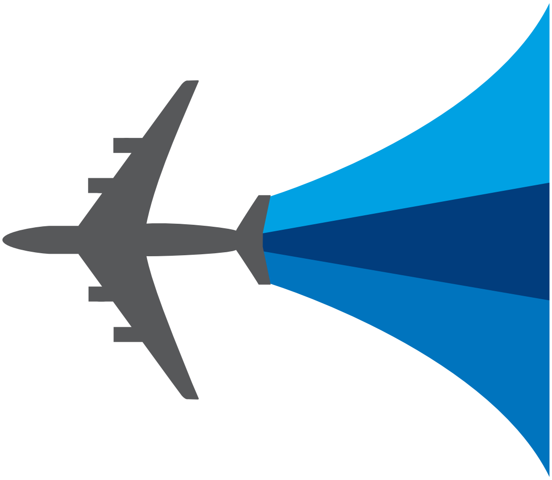

# PART II

# NEEDS AND TECHNOLOGICAL CAPABILITIES

## 7 TECHNOLOGY DRIVERS

Augusto Barbosa Cortez [et al.]. "Technology Drivers", p.115-126. In: Luís Augusto Barbosa Cortez (Editor). **Roadmap for sustainable aviation biofuels for Brazil — A Flightpath to Aviation Biofuels in Brazil**, São Paulo: Editora Edgard Blücher, 2014.
http://dx.doi.org/10.5151/BlucherOA-Roadmap-007

# 7 TECHNOLOGY DRIVERS

## 7.1 Feedstock

In the experts panel the technology drivers were discussed considering the three pillars set beforehand for jet biofuel production within this roadmap: a) reduce production costs, b) ensure that biofuels are environmentally sustainable, and c) that biofuel production improves rural development. The main technology drivers, summarized in **Table 19** to **Table 22**, are presented individually and distributed according to the critical system requirements. Only drivers explicitly mentioned in the workshop by the speakers are presented below.

For plant feedstocks, genetic improvement and crop management practices were the main technological to meet most critical systems requirements. The technology drivers varied according to group of plants or specific crops, because crops are in different stages of technological development and cultivation in Brazil. Sugarcane, soybeans and eucalyptus are widely cultivated and have strong R&D bases, but jatropha and camelina are relatively new crops in Brazil. For instance, for jatropha, detoxification of residues, and mechanized harvest were considered important drivers to reduce feedstock prices. Different aspects or problems were emphasized by the experts assembled in different groups. However, it seems clear that most improvements can be obtained with research in areas such as plant breeding and agricultural practices. The use of modern technologies such as molecular biology and precision agriculture can speed up progress.

Technology drivers for improving rural development were not pointed out in most expert panels. The prevalent opinion was that modernization of agriculture per se, which is necessary to produce feedstock for aviation biofuel, tends to decrease job numbers for unskilled laborers but increase overall opportunities in the farms and, especially, in the small towns and rural communities. The improved infrastructure, the increased consumption of seeds, machines, agrochemicals, services, etc, will foster economic growth. In addition, more organized businesses, both at the farm level as well as that of suppliers and other components of the biofuel chain, tend to offer better quality jobs, which abide by labor laws and regulations.

**Table 19 Oils Group.**

| GOAL | OIL CROPS | CRITICAL SYSTEM REQUIREMENT (CRS) | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Reduce Production Costs** | *Soybean* | CSR#1 Increase feedstock yield and CSR#2 Reduce feedstock Costs | Genetic improvement | - Drought tolerance |
| | | | | - Rust resistance |
| | *Palm* | CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs | Plant breeding | - Resistance to bud rot |
| | | | | - High efficiency cloning system |
| | | | Seed production | - Expand seed production |

**Table 19 Oils Group (continued).**

| GOAL | OIL CROPS | CRITICAL SYSTEM REQUIREMENT (CRS) | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Reduce Production Costs** | *Camelina* | CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs | Genetic improvement | - Suitable new camelina varieties |
| | | | | - Oil content increase |
| | *Jatropha* | CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs | Genetic improvement/ breeding | - Superior genotype selection, matched to local conditions: even ripening |
| | | | Crop management | - Disease control |
| | | | | - Fertilization |
| | | | | - Spacing |
| | | | | - Growth regulators |
| | | | | - Pruning |
| | | | | - Phenology management |
| | | | | - Mechanized harvest |
| | | | Residues | - Residues detoxification |
| | | | | - Alternative uses for residues |
| **Environmental Sustainable biofuels** | *Soybean* | CSR#3 Reduce GHG emissions/Potential $CO_2$ net reduction per ha | By-products | - Use of biodiesel by machinery |
| | *Camelina* | CSR#3 Reduce GHG emissions/Potential $CO_2$ net reduction per ha | Crop management | - No tilling |
| | | CSR#5 Land use | Land choice | - Marginal, degraded land |
| | | | | - Fallow land |
| | | | | - Rotation with traditional cereal |
| **Improve regional development** | *Soybean* | CSR#7 Reduce impacts on environment | Crop management | - Mitigation of nitrogen volatilization ($N_2O$) from soybean straw |
| | *Camelina* | CSR#8 Rural development and employment | Animal feed development | - NA |

**Notes:**

No information on critical system requirements on the goals of environmental sustainable biofuels" and "improving region development" provided for palm and jatropha.

## Table 20 Sucrose Group.

| GOAL | SUCROSE | CRITICAL SYSTEM REQUIREMENT | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Reduce Production Costs** | *Sugarcane* | CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs | Plant breeding | - Traditional breeding programs |
| | | | | - Transgenic |
| | | | Logistics | - Pipelines |
| | | | | - Cost of harvest, collection, and transportation |
| | *Sweet sorghum* | CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs | Plant breeding | - Conventional, MAS breeding |
| | | | | - Traits - drought/stress tolerance |
| | | | | - Fertilizers/ripeners |
| | | | Crop management | - Fermentation (sugar + starch) |
| | | | Industrial processing | - Cellulosic hydrolysis |
| | *Cassava* | CSR#1 Increase feedstock yield | Plant breeding | - Varieties for the production of biomass |
| | | CSR#2 Reduce Feedstock Costs | Crop management | - More efficient production systems |
| | | | | - Mechanization |
| | | | | - Development and implementation of drying technologies inside the property |
| | | | Residue and by-products | - Development and use of by-products and residue use |
| **Environmental Sustainable biofuels** | *Sugarcane* | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha | Plant breeding | - Traditional breeding programs |
| | | | | - Mechanization of harvest |
| | | | Crop management | - Biological pest control |
| | | | | - Residue use |

**Table 20 Sucrose Group (continued).**

| GOAL | SUCROSE | CRITICAL SYSTEM REQUIREMENT | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Environmental Sustainable biofuels** | *Sugarcane* | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha | Crop management | - Soil management and farm practices |
| | *Sweet sorghum* | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha and CSR#4 Energy balance | Plant breeding | - Conventional breeding, MAS |
| | | | Crop management | - Minimum tillage |
| | | | | - Mechanical harvest |
| | *Cassava* | CSR#6 Agrochemical use | Crop management | - Biological control (almost no use of agrochemicals) |
| | | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha | Plant breeding | - Genetic resources for all biotic and abiotic stresses |
| | | | Crop management | - Low consumption of nitrogen |
| **Improve regional development** | *Sugarcane* | CSR#8 Rural development and employment | NA | - Formal contracts |
| | | | | - Number of employees sector |
| | | | | - Monthly earning in the sector |
| | | | | - Schooling |
| | *Sweet sorghum* | CSR#8 Rural development and employment | Plant breeding | - Non sugarcane feedstock suppliers |
| | | | | - Non sugarcane ethanol producers (microdistilleries) |
| | | | Crop management | - Safrinha sweet sorghum producers |
| | *Cassava* | CSR#8 Rural development | NA | - NA |

**Table 21 Cellulosic Group.**

| GOAL | CELLULOSE | CRITICAL SYSTEM REQUIREMENT | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Reduce Production Costs** | Eucalyptus | CSR#1 Increase feedstock yield | Plant breeding | - Hybridization and cloning |
| | | | | - Improvements of species for resistance to diseases and pests |
| | | | | - Adaptation of species for areas with water or frost stress |
| | | | | - Transgenic technologies |
| | | | Crop management | - Mechanization and automation of silvicultural practices and harvesting |
| | Grasses | CSR#1 Increase feedstock yield | Plant breeding | - Selection of elephant grass genotypes of high productivity and quality to be used as alternative energy source |
| **Environmental Sustainable biofuels** | Eucalyptus | CSR#7 Reduce impacts on environment | Crop management | - Improve efficiency of water use |
| | | | | - Maintain or increase biodiversity in the landscape |
| | | | | - Reduce soil erosion |
| | | | | - Maintain or increase the nutrient stock in the ecosystem |
| | Grasses | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha | Crop management | - Biological fixation of nitrogen |
| | | | | - Reduce the emission of carbon |

**Notes:**
No information on critical system requirements for Paulownia. No information on critical system requirements on the goal of “improving region development” provided for any of the cellulosic feedstocks.

**Table 22 Wastes Group.**

| GOAL | WASTES | CRITICAL SYSTEM REQUIREMENT | LARGE TECHNOLOGICAL AREAS | TECHNOLOGY DRIVERS |
|---|---|---|---|---|
| **Reduce Production Costs** | Municipal Solid Waste | CSR#2 Reduce feedstock costs (Collection costs) | Logistics | - Maximize waste volume for each collection truck |
| | | | | - Reduce transportation time and distance for the collection |
| | | | | - Use fuel efficient vehicles |
| | | | Collection vehicle | - Decrease labor required for pick-up |
| **Environmental Sustainable biofuels** | Municipal Solid Waste | CSR#3 Reduce GHG emissions/ Potential $CO_2$ net reduction per ha | Landfill Emissions | - Decrease methane emissions in landfill by diverting biogenic MSW to Terrabon process |
| | | | | - Optimization of truck hauls for feedstock supply and product |
| | | | Plant design | - Incorporate new technologies for energy recovery |
| | | | | - Improve Fuel Carbon Intensity of biofuel |
| **Improve regional development** | Municipal Solid Waste | CSR#8 Rural development and employment | Biofuel Plant | - Engineering jobs |
| | | | | - Management and operation jobs |
| | | | | - Construction jobs |
| | | | | - Hauling jobs |
| | | | Food waste collection | - Contaminant separation jobs |

**Note:**

No information on critical system requirements for other feedstocks in waste group.

The information on targets to be attained in 2020 and 2050 was only provided in the minority of cases and, therefore, will be addressed in the text rather than listed in **Table 19**, **Table 20**, **Table 21** and **Table 22**. In the oils group, specifically for soybean (regarding the goal to reduce production costs), the targets for 2020 and 2050 from genetic improvement to develop drought and rust tolerant traits was set at 5% and 25% respectively for both critical system requirements (increase feedstock yield and reduce feedstock costs). This means that costs would be reduced by 5% and 25%, respectively, in 2020 and 2050 with plant breeding and productivity would increase by 5% and 25% respectively in the same years with plant breeding. It should be noticed that yield increases with current technology are possible (**Table 16**). The same applied for a variety of cultivated feedstocks. On the goal of environmental sustainable biofuels, specifically for soybeans, the use of biodiesel by machinery is targeted to reduce potential $CO_2$ net emission per ha in 5% by 2020.

For jatropha, also in the oils group, genetic improvement/breeding for superior genotype selection and disease control was expected to increase feedstock yields by 100% and 50%, respectively, in 2020. Crop management, specifically through fertilization, spacing, growth regulators, pruning, and phenology management was also said to increase feedstock yield in 2020, where: spacing (40%); growth regulators (400%); pruning (40%), and phenology management (100%).

In the sucrose group, specifically for sugarcane, plant breeding (through traditional breeding programs and transgenic varieties) is expected to increase feedstock yield by 25% by 2020. In the case of sweet sorghum, plant breeding through conventional breeding and drought and stress tolerant traits is expected to increase feedstock yields by 100% and 20%, respectively, by 2020. Also for sweet sorghum, crop management through fertilizers/ripeners is expected to increase feedstock yield by 20% by 2020. Still for sweet sorghum, industrial processing through fermentation (sugar+starch) and cellulosic hydrolysis) is expected to increase yields by 50% and 100%, respectively, by 2020. In terms of cost reduction, plant breeding in sweet sorghum through conventional breeding and drought and stress tolerant traits is expected to reduce costs by 40% and 10%, respectively, by 2020. Minimum tillage and harvesting (crop management) in sweet sorghum production are expected to reduce costs by 10% and 30%, respectively.

No targets were established for the other feedstocks in the sucrose group. Also, no targets were established for the cellulosic group. In the waste group, specifically for municipal solid waste (MSW), reducing transportation time and distance for collection was targeted to reduce collection costs by 2% by 2020 and by 3% by 2050. Also, decreasing labor required for pick-up (through changing collection vehicles) would also reduce collection costs by 2% by 2020 and 5% by 2050. Still regarding MSW, improving fuel carbon intensity of biofuel would reduce landfill potential emissions by 2% in 2020 and by 5% in 2050. Furthermore, in plant design, incorporating new technologies for energy recovery would reduce potential GHG emissions by 4% in 2020 and 6% in 2050. Lastly, with regard to the rural development goal, food waste collection, through separation jobs, would improve rural development by 5% in 2020 and 10% in 2050. Construction jobs in biofuel plants would also increase development by 2% in 2020 and 4% in 2050 and management and operation jobs by 5% in 2020 and 15% in 2050.

## 7.2 Refining Technologies

**Table 23 Technology drivers for pretreatment of biomass technologies.**

| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
|---|---|---|---|
| **1. Pyrolysis** | | | |
| requires lower cost of equipment | *High losses* (1), *high costs* | 0.8 | 0.7 |
| requires development of larger plants | (1), *high costs* | 0.8 | 0.6 |
| requires higher robustness to low density biomass | *High losses* (1), *high costs* | 0.9 | 0.8 |
| **2. Steam explosion** | | | |
| requires better design of equipment for large scale | High cost (1), needs equipment for scaling-up | 0.9 | 0.8 |
| requires high pressure vapour | High cost (1) | 0.9 | 0.8 |
| better controlled process conditions | High cost (1) of investment | 0.8 | 0.7 |

**Table 24 Technology drivers for conversion technologies.**

| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
|---|---|---|---|
| **1. Hydrolysis** | | | |
| requires more selective specific and robust enzymes | *Long times required* (1), *high costs* | 0.8 | 0.7 |
| cheaper enzymes | *Large doses, required* (1), *high costs* | 0.8 | 0.6 |
| faster enzymes | *Large doses, required* (1), *high costs* | 0.8 | 0.6 |
| requires more homogeneous biomasses | Expensive (1) | 0.9 | 0.8 |
| needs cheaper and more efficient enzymes. | Expensive (1) | 0.8 | 0.6 |

| Table 24 Technology drivers for conversion technologies (continued). | | | |
|---|---|---|---|
| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
| **2. Liquefaction** | | | |
| requires more systematic studies of solvent mixtures. | Intermediate (1) | 0.8 | 0.6 |
| requires recycling of the solvents and catalytic up grading of the products. | Intermediate (1) | 0.8 | 0.6 |
| **3. Gasification** | | | |
| requires high efficient pressure equipment | Expensive cost (1) | Reduction to 0.5 | Reduction to 0.25 |
| requires efficient catalysts for conversion to synthesis gas | High losses (1), high costs | 0.8 | 0.5 |
| needs better equipment efficiency for wet biomass | High losses (1), high costs | 0.9 | 0.7 |
| **4. Fast pyrolysis** | | | |
| requires scale-up of existing pilot plants. | Medium cost (1), efficient | 0.8 | 0.6 |
| requires optimization of pyrolysis conditions to produce high yields of bio-oil. | Needs systematic study (1) | 0.8 | 0.6 |
| **5. Fermentation to alcohols** | | | |
| better yields | High cost (1) | 0.8 | 0.8 |
| lower $CO_2$ emission | High $CO_2$ emission (1) | 0.8 | 0.8 |
| fermentation to alcohols or precursors using solid municipal waste | | | |
| Requires efficient separation / fractionation (Residues and wastes collection: in the site where the residue is produced and the transportation of the residue to the industrial facility.) | needs to be developed (1) | 0.5 | 0.2 |
| fermentation using municipal waste requires more specific conversion process for each fraction | needs to be developed (1) | 0.5 | 0.3 |
| fermentation using industrial residues | More technology required, more investment (1) | 0.6 | 0.3 |

**Table 24 Technology drivers for conversion technologies (continued).**

| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
|---|---|---|---|
| fermentation to alcohols/precursors using flue gases | More technology required, more investment (1) | 0.6 | 0.4 |
| fermentation to alcohols/precursors using sewage | More technology required, more investment (1) | 0.6 | 0.3 |
| **6. Fermentation to lipids** | | | |
| requires higher conversion of sugars and higher yields to lipids | More technology required, more investment (1) | 0.7 | 0.5 |
| requires faster microbial metabolism & higher productivities | More technology required, more investment (1) | 0.7 | 0.5 |
| requires more robust yeasts/microalgae to be used in an industrial scale | More technology required, more investment (1) | 0.8 | 0.7 |
| requires cheaper feedstock as lignocellulose and wastes. | More technology required, more investment (1) | 0.8 | 0.6 |

**Table 25 Technology drivers for jet fuel production technologies.**

| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
|---|---|---|---|
| **1. HEFA** | | | |
| requires cheaper microbial oils | more investment (1) | 0.8 | 0.6 |
| requires extraction and pretreatment of oil | More technology required, more investment (1) | 0.8 | 0.6 |
| requires standardization of feedstock. | More technology required, more investment (1) | 0.8 | 0.6 |
| Requires cheaper hydrogen | Cheaper/ more abundant hydrogen sources | | |

**Table 25 Technology drivers for jet fuel production technologies (continued).**

| DRIVERS | TODAY (*1 refers to current condition*) | 2020 (*numbers reflect relative progress from current condition*) | 2030-2050 (*numbers reflect relative progress from current condition*) |
|---|---|---|---|
| **2. Alcohol to jet fuel** | | | |
| requires more selective catalysts which would convert the alcohols more efficiently to jet fuels. | More technology required, more investment (1) | 0.8 | 0.5 |
| Requires better industrial plants. | Less operation steps, too expensive (1) | 0.8 | 0.4 |
| Requires simpler technology. | Too complicated (1) | 0.7 | 0.5 |
| Requires higher yields | Low yield (1) | 0.8 | 0.7 |
| **3. Fischer Tropsch** | | | |
| Requires efficient high pressure equipment. | Too high pressure required, expensive (1) | 0.8 | 0.6 |
| Requires efficient catalysts. | Better catalysts needed, expensive (1) | 0.8 | 0.7 |
| Requires large amounts of biomass to optimize the costs. | Requires more concentrated/ dense feedstock | 0.9 | 0.8 |
| **4. Direct sugars to hydrocarbon (DSHC)** | | | |
| Requires better use of sugars (less by-products). | Low conversion, low yields, too expensive (1) | 0.9 | 0.7 |
| Requires standard sterilization equipment for genetically modified microorganism. | Easier contamination than bioethanol, standard sterilization protocol is required, more expensive (1) | 0.8 | 0.5 |
| **5. Bio-oil upgrading** | | | |
| Requires cheaper catalysts. | Expensive catalysts used (1) | 0.7 | 0.5 |
| Requires hydrogen transfer from cheap sources. | Molecular hydrogen used (1) | 0.7 | 0.5 |