



CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

Rio de Janeiro, Brazil, 16 to 18 November 2009

Agenda Item 2: Technological feasibility and economic reasonableness

U.S. RESEARCH AND DEVELOPMENT ROADMAPS FOR ALTERNATIVE AVIATION JET FUELS

(Presented by the United States)

SUMMARY

The Commercial Aviation Alternative Fuels Initiative (CAAFI) utilizes a series of roadmaps that identify achieved and anticipated milestones in the development and deployment of alternative aviation jet fuels. CAAFI uses these roadmaps to track overall progress in alternative jet fuel efforts and to identify gaps in activities to which research and resources can be channelled as needed. The Research and Development (R&D) roadmaps also distinguish between work that has been accomplished, is currently planned for execution or has been identified by CAAFI's R&D team as an unmet need. In this information paper, the United States (U.S.) presents a summary of the information contained in the R&D alternative aviation jet fuels roadmaps developed by CAAFI, which are appended.

1. INTRODUCTION

1.1 The US Federal Aviation Administration created the Commercial Aviation Alternative Fuels Initiative (CAAFI) in 2006 in response to three key concerns regarding aviation fuel: energy security, cost, and environmental factors. Since its inception, CAAFI has focused on four key areas relating to the development and deployment of alternative jet fuels: economics/business, certification, environment, and research and development. To assist in planning and coordinating alternative fuel activities, CAAFI undertook a roadmapping effort to identify and track the progress of the steps required to effectively support: the facilitation of economic and business steps required for deployment, the certification of drop-in alternative jet fuels, the scientific assessment of environmental benefits of incipient alternative fuels, and development of alternative aviation jet fuel technology, processes, and feedstocks. The original roadmaps were developed in preparation for the 23 to 24 October 2006 meeting at Georgia Institute of Technology, and are generally updated on a biannual basis. This

work is being presented to ICAO to indicate the important research and development areas that are being tracked by CAAFI.

1.2 This paper presents an overview of CAAFI's Roadmaps and a summary of the steps required of governmental, commercial, and academic institutions in the development, assessment and deployment of alternative aviation jet fuels. These roadmaps also identify areas where activities are underway and those where gaps exist in current activities.

1.3 This information paper is submitted to inform deliberations at the Rio de Janeiro, Brazil meeting.

2. ROADMAP STRUCTURE AND GOALS

2.1 CAAFI has developed a series of roadmaps that provide overview and detailed projections of milestones leading to successful development and deployment of alternative aviation jet fuels. These roadmaps are based on CAAFI stakeholder input, and CAAFI teams update their roadmaps approximately every six months based on participant knowledge and publicly available information. The different levels show progressively more detailed projections of activities and needs within each area of CAAFI involvement.

2.2 The Level 1 Roadmap (appended) is a high level overview of the drivers behind the transition to alternative aviation jet fuels (i.e., peak oil production, climate change) and general estimates when particular drop-in alternative jet fuels suitable for aviation will be available. The goals of this level are to identify the potential alternative fuels that may come to market in the next half century and to estimate the timing of availability at a very general level.

2.3 The Level 2 Roadmaps (appended) identify four key areas, addressed by the four CAAFI teams, in which alternative fuels activities must occur to advance deployment: Economics/Business, Airworthiness Certification, Environment, and Research and Development (R&D). To parallel the Level 1 roadmap, the teams have developed more detailed roadmaps for each key area within the long-term timeframe outlined by the Level 1 Roadmap. The purposes of the Level 2 Roadmaps are as follows:

2.3.1 Economics/Business: To identify, plan and coordinate key steps in the development of an alternative fuels industry with regard to procurement, supply and demand.

2.3.2 Airworthiness Certification: To identify key steps to standardization and specification acceptance for alternative fuels and the certification of near-term, drop-in fuels for planning and coordination purposes.

2.3.3 Environment: To plan and coordinate evaluation of environmental impacts from near-term, drop-in fuels.

2.3.4 R&D: To identify, plan and coordinate the required activities and timeframe for research, overcoming of technical barriers, and development of alternative fuels and fuel production.

2.4 The Level 3 Roadmaps cover planned and needed activities over the next 8 to 10 years. These roadmaps project detailed, near-term milestones and achievements in development, evaluation and deployment of alternative jet fuels for aviation within each area covered by the Level 2 Roadmaps. These milestones can be used as benchmarks for progress in the alternative jet fuels development and deployment efforts.

3. RESEARCH AND DEVELOPMENT ROADMAPS

3.1 The milestones and dates depicted in the R&D roadmaps were projected by the CAAFI R&D team, which includes representatives from government, academia, airlines, original equipment manufacturers (OEM's), small and large industrial partners, government and other laboratories, fuel producers and researchers, with some foreign participation. As with the other roadmaps, CAAFI updates these R&D Level 3 roadmaps approximately every six months.

3.2 (*Level 2) Goals:* To identify the timeframe for research, overcoming of technical barriers, and development of alternative fuels and fuel production. This timeline (appended) creates a general, long-term outline for new fuel testing and deployment of the following: testing of renewable alternative aviation jet fuels in various engine types, including flight tests; development of bio-jet (lab testing through approval), bio-jet from algae, and advanced aviation biofuels; and testing of synthetic and bio-jet characteristics and improvement of specifications.

3.3 (*Level 3) Goals:* To create shorter term, more detailed plans based upon the information developed for the Level 2 Roadmap. The Level 3 R&D Roadmaps (appended) identify research and development activities for a variety of fuel producers, vehicle producers (users), governmental agencies and academia in the following areas:

- a) Feedstock production development: Feedstock production development is critical to successfully implement alternative aviation fuel certification and deployment. Certification of fuels hinges in part on the availability of sufficient quantities of fuel for suitability and certification testing. Successful deployment of alternative aviation jet fuels cannot occur unless sufficient product is available to provide the industry with a minimum suitable level of substantial replacements for petroleum-based jet fuel. Multiple feedstocks are likely to be required to meet the needs of airports while limiting the transportation requirements for distribution of biofuels, as long-distance transportation of alternative fuels is detrimental to cost-competitiveness and the environmental goal of greenhouse gas (GHG) reduction. As part of the roadmap development, CAAFI has identified areas in which action is still needed, including: optimization of cultivation, harvesting and plant development for jatropha, algae, cyanobacteria, halophytes, cellulosic and other feedstocks; genetic modification of suitable feedstock plants for increased sugar or lipid production, development of regional solutions to feedstock production; development of cellulose to drop-in jet fuel via synthetic biology processes; development of complete pyrolytic cellulose to biojet demo plant and system; and suggested initiation of a U.S. Department of Agriculture advanced biofuel program to develop biomass supply;
- b) R&D Planning Activities: R&D planning activities timeline covers technology planning studies and workshops to define new research and development needs for different agencies/stakeholders. As part of this process, CAAFI identified the need for an active, comprehensive integrated roadmap of R&D activities, which CAAFI has met by producing these Level 3 R&D roadmaps. This timeline also includes the CAAFI and R&D team meetings as events that contribute to R&D planning;
- c) Certification protocol development: This timeline dovetails with the CAAFI Certification Team and identifies areas where more R&D work is needed to define certification protocols and strategies and to codify certification requirements for alternative aviation jet fuels;

- d) Performance Studies: These studies investigate possible performance or fuel system impacts of alternative fuels in aircraft and engine systems addressing the question of whether the alternative fuels require changes in aircraft operations or mission planning due to changes in fuel heating value, density, or other characteristics;
- e) Fuel property testing (commercial and military): studies of materials compatibility, thermal traits and other characteristics are a crucial component of novel alternative fuels testing to ensure compatibility with existing infrastructure and “drop-in” status. This testing also provides needed information to prepare for possible fuel certification;
- f) Component and engine testing (commercial and military): After laboratory materials testing and characteristics studies, novel alternative fuels must be exercised in aviation settings, including component, engine and vehicle testing. This roadmap identifies testing to be performed which may be required for some renewable fuels, dependent on the outcome of steps primarily identified in the new fuel approval process (ASTM D4054) or the requirements for meeting fuel specifications (e.g., ASTM D7566). These milestones are provided for reference on the R&D roadmaps as they directly support the certification process, and they will appear on the CAAFI Certification team roadmaps (not shown) as well. Engine and flight testing for various fuels and vehicles has begun, but further work is envisioned in this area;
- g) Flight testing (commercial and military): This final stage of development testing occurs after laboratory fuel property testing and component and engine testing. Both commercial jets and various military vehicles and operation types (high altitude flights, for example) must be tested to confirm appropriate fuel behavior in situ (although flight testing is not required for certification of commercial aircraft fuels);
- h) Production studies: Analytical studies to investigate and optimize alternative fuel production processes. R&D team members have suggested several potentially useful studies during the roadmapping process, including a study of requisite biomass and production quantities, and a study on alternative cellulosic biomass processes;
- i) Production R&D: In order to scale up production to allow significant deployment in aviation that will improve cost, and demonstrate process repeatability and reliability at production scale, further manufacturing research and development is necessary for some production processes. This roadmap identifies process, research, and pilot scale facilities to develop and demonstrate alternative fuel processes in preparation for scaling-up to commercialization. FT and hydrotreated renewable jet fuel (HRJ) production engineering, engineering of algal and cellulosic biofuel production facilities and development of ethanol oligomerization plants are among the items identified as having long-term potential for alternative aviation fuel production. Several production areas have been identified as having unmet needs, including the development of alternative biomass processes (cellulosic pathways), the development of subscale drop-in hydrotreated renewable jet fuel production, and lab/pilot production of cellulosic ethanol oligomerization to jet fuel;
- j) Other: Other activities of interest to researchers including environmental and life cycle studies and efforts needed to support commissioning and construction of production facilities. As is the case with production qualification/certification, this information is provided for reference of R&D planners. Thus, we have included milestones that are also included in

CAAFI Environmental and Business roadmaps where they are described in detail and where the analyses take place. Objectives that have not yet been initiated include the construction, commission and start-up of renewable oil refinery, and the development of commercial cellulosic ethanol oligomerization to jet fuel.

4. **EXPECTED OUTCOMES OF R&D ROADMAPS:**

- 1) Identification of needed comprehensive studies of key near-term alternative fuels with regard to properties, specifications, production, processing, and use.
- 2) Data to form basis for certification process as developed by Certification Team.
- 3) Identification of research and funding gaps.
- 4) Measurement of progress in alternative fuel development and deployment when roadmaps are updated, which in turn informs the Fuel Readiness Level evaluation for fuels in development.
- 5) Interaction with environmental assessment teams at appropriate points during development.

5. **SUMMARY**

5.1 This paper provides a summary of Level 1 roadmap, Level 2 team roadmaps and the Level 3 R&D roadmaps produced by CAAFI. In addition, this paper indicates areas of opportunity in the development, assessment, and deployment of alternative aviation jet fuels. CAAFI is providing these roadmaps as a baseline for tracking alternative aviation fuel progress. The roadmaps appended herein provide projections as estimated by industry participants as of October 1, 2009 and are subject to continuous update. It is recommended that those interested in the most current information submit inquiries through the CAAFI website www.caafi.org.

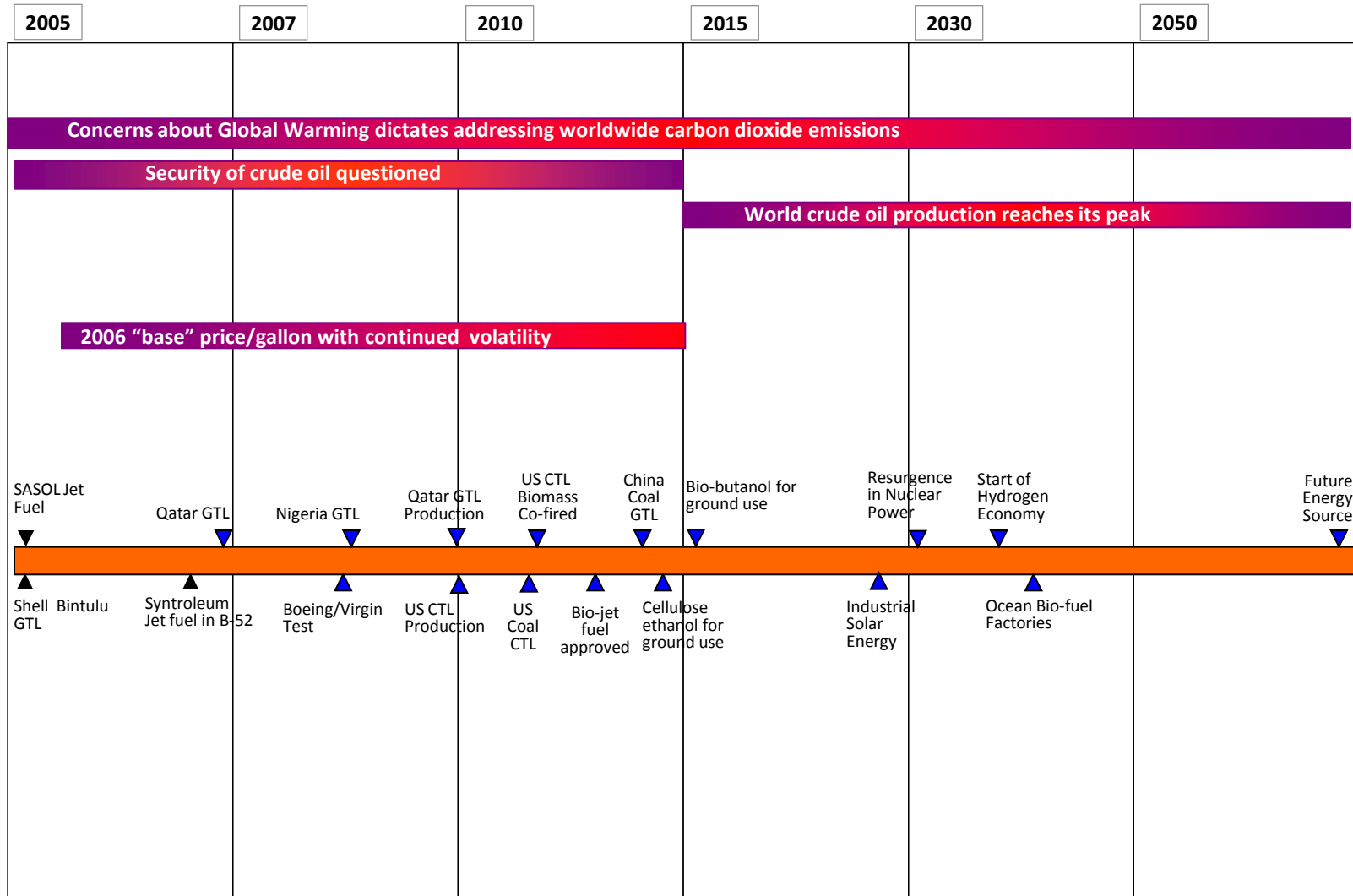
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Aviation Alternate Fuels Roadmap

Draft

(Level 1 / Scenario 1)

Category

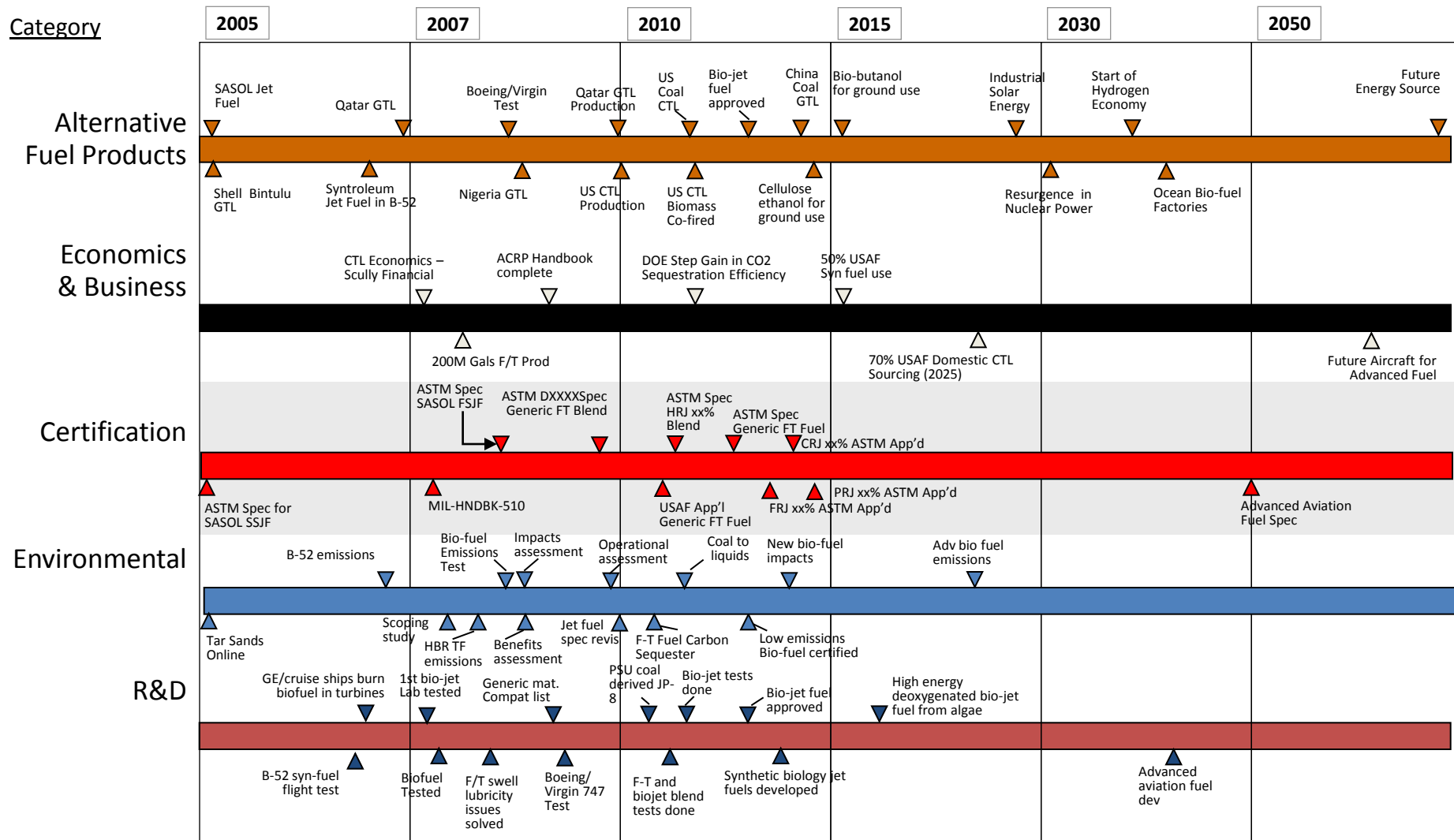


* Fuels produced from seeds and other organic sources such as Soybean Methyl Ester

Aviation Alternate Fuels Roadmap

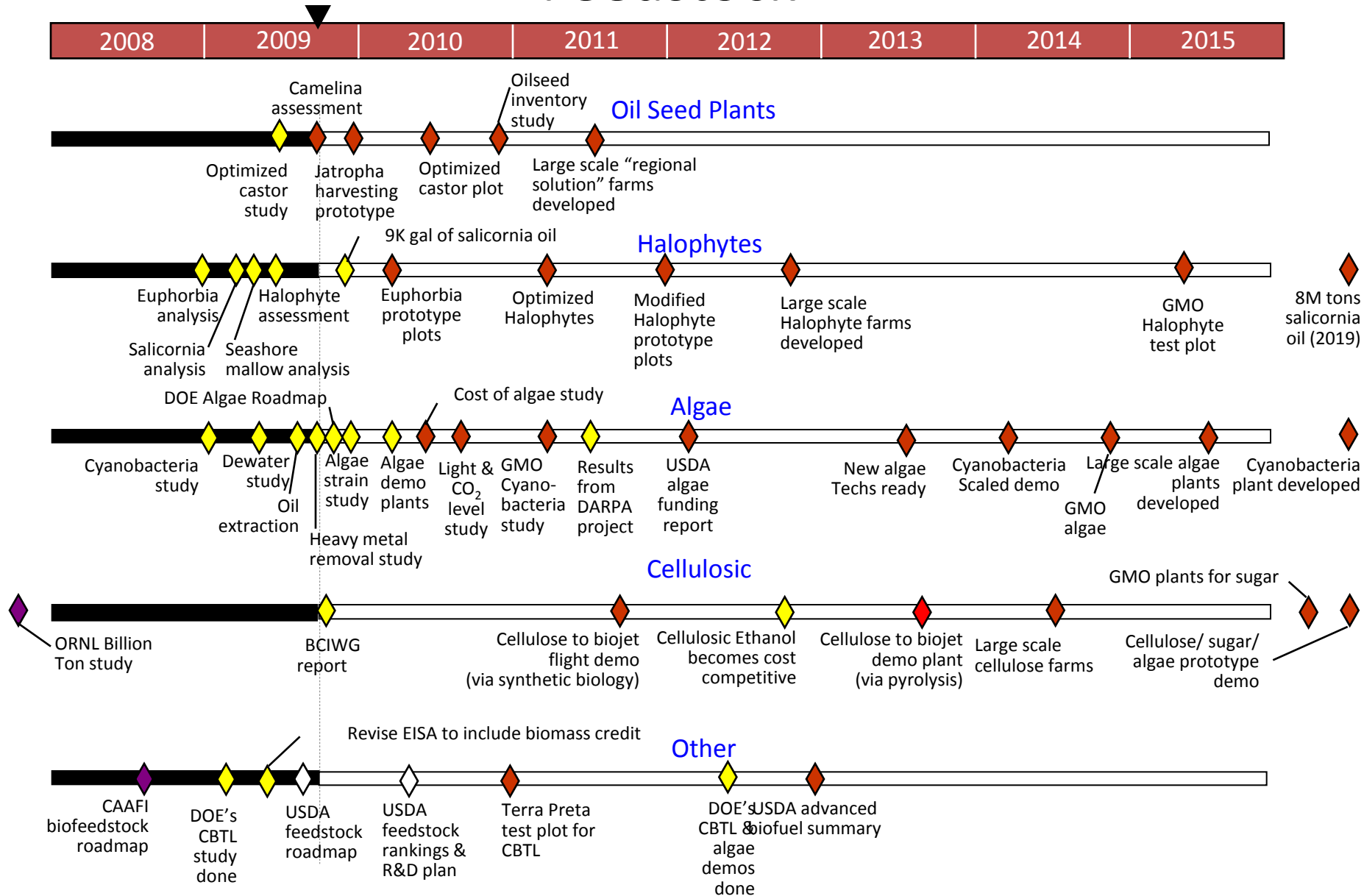
(Level 2 / Scenario 1 - Long Term)

Category



CAAFI R&D Team Roadmap (1 of 6)

Feedstock

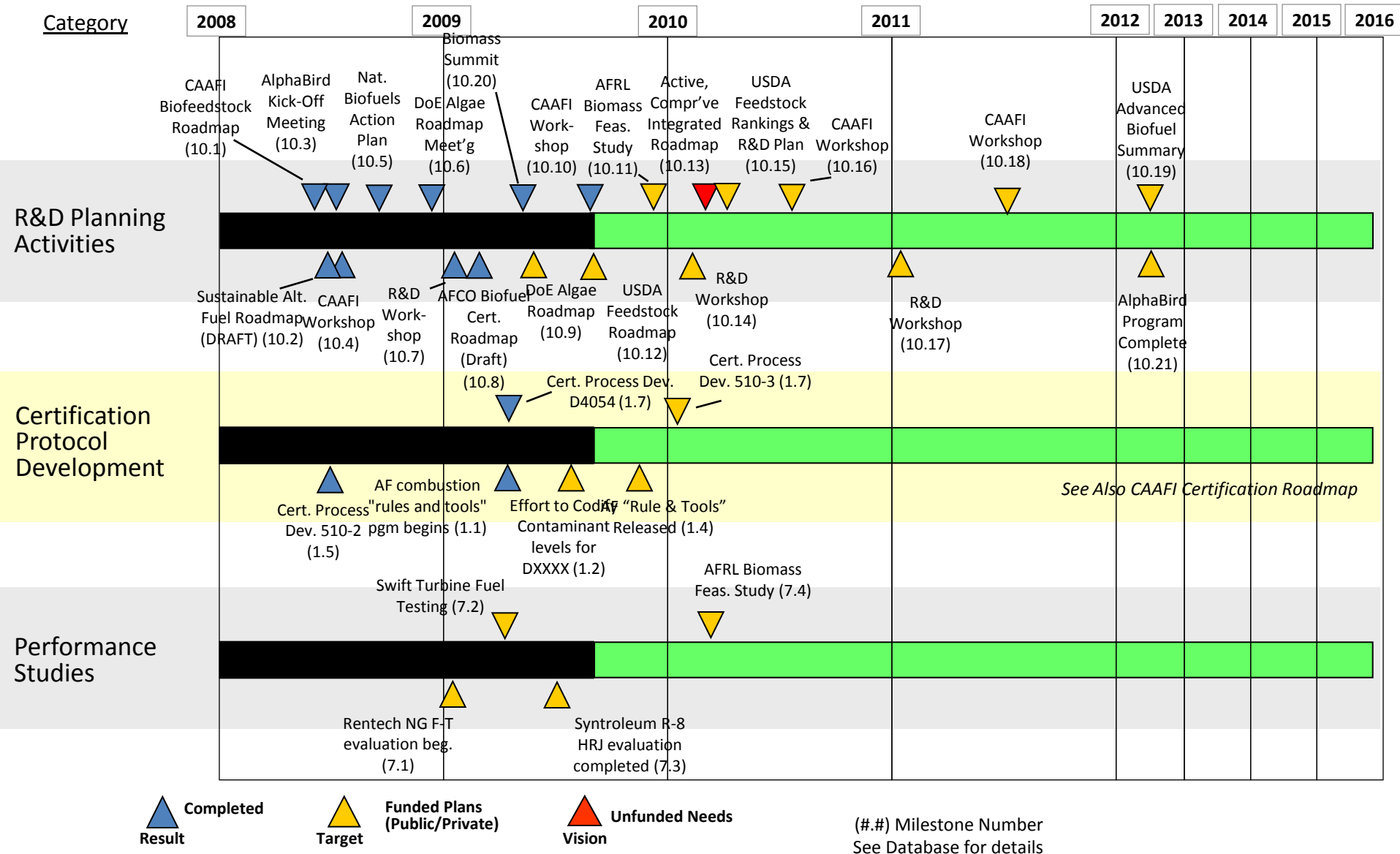


*LCAs of biofuels are included in the Environmental team's roadmap

◆ = Done ◆ = In work ◆ = Not Funded

CAAFI R&D Team Roadmap (2 of 6)

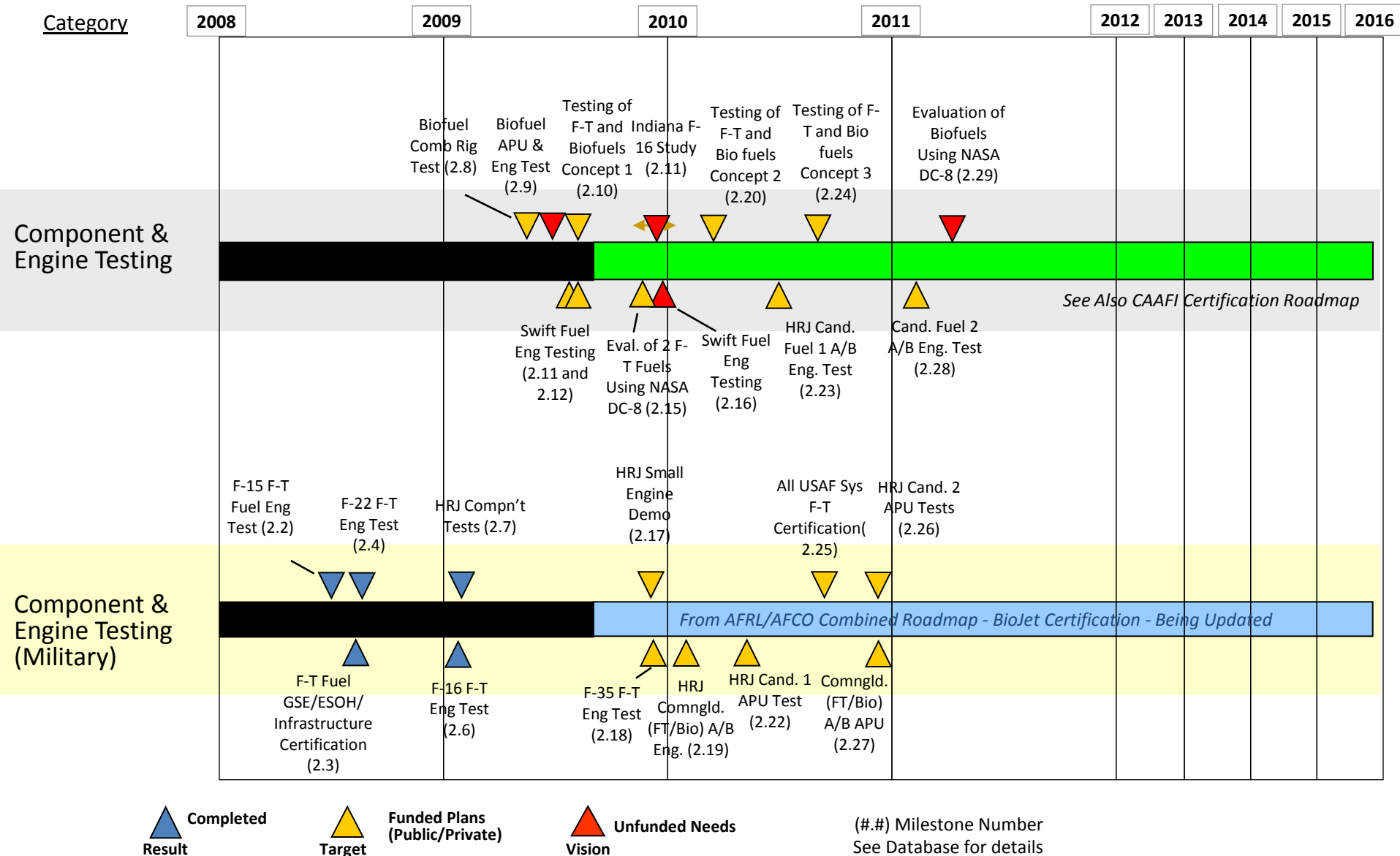
Planning, Protocol, and Performance



Fuel Property Testing



Component and Engine Testing



Flight Testing

 **Completed**
Result

 **Funded Plans
(Public/Private)**
Target

 **Unfunded Needs**
Vision

(#.#) Milestone Number
 See Database for details

CAAFI R&D Team Roadmap (6 of 6)

Production Studies and R&D

