Wood to green gasoline using Carbona gasification and Topsoe TIGAS processes - DOE Project DE-EE0002874

RESEARCH | TECHNOLOGY | CATALYSTS

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HALDOR TOPSØE

Acknowledgment & disclaimer

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Jim Patel, Project Manager, Carbona/Andritz
Jesper H. Jensen, Project Manager, Haldor Topsoe A/S
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Pekka Jokela, Project Manager, UPM-Kymmene

Wood to green gasoline project

U.S. Department of Energy
Golden Field Office

DOE Award No.
DE-EE0002874

DOE Program Manager:
Paul Grabowski

Government share:
$ 25,000,000

Cost share:
$ 9,388,775

Period of performance:
12/28/09 through 12/31/14

HALDOR TOPSØE

Project partners

UPM

UPM is one of the world's largest pulp and paper companies, with over 100 facilities.
Provides: gathering, handling and transporting of wood; 1st commercial plant site

HALDOR TOPSOE
CATALYSING YOUR BUSINESS

Haldor Topsoe is a leading worldwide supplier of catalysts and catalytic technology for fuel conversion and upgrading.
Provides: TIGAS process, syngas cleanup including tar reforming and conversion; overall project management

PHILLIPS 66

Phillips 66 Company is a leading oil refiner & contributor to TIGAS
Provides: Liquids fuels handling, transportation and marketing, sample characterization, pilot plant design, construction, opera-tion and scale-up assistance

CARBONA

Carbona is a supplier of biomass gasification and gas cleanup plants
Provides: fluidized-bed gasification, tar reforming, commercialization support

gti

GTI is the developer of gasifi-cation technology, licensor of acid gas removal process, and owner/ operator of pilot plant test facility
Provides: design, construction, and operation of pilot plant plus modeling, data analysis, commercialization support

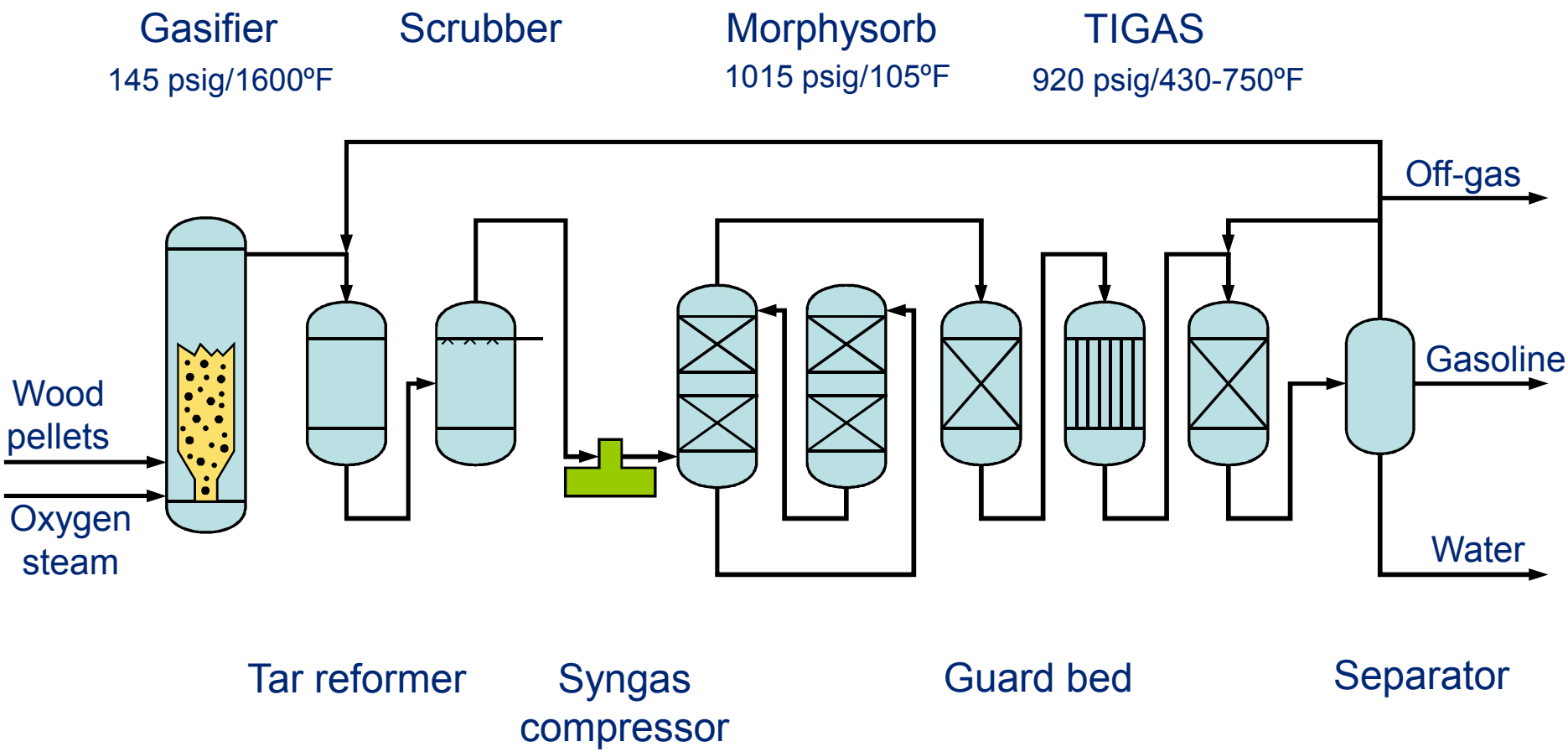
Project Go/No-Go Points

Decision point	Basis	Month/year
1. Complete preliminary design package	Preliminary HAZOP - *completed*	Nov 2010
2. Complete detailed design package	Final HAZOP - *completed*	Apr 2011
3. Proceed with BP-2	Final design review, capital cost update - *completed*	May 2011
4. Proceed with procurement	Major bids received and evaluated - *completed*	Sep 2011
5. Proceed with shakedown	Feedstock received in acceptable condition - *completed*	Nov 2012
6. Proceed with Test Campaign	Independent Engineer Test approval - *completed*	Oct 2013

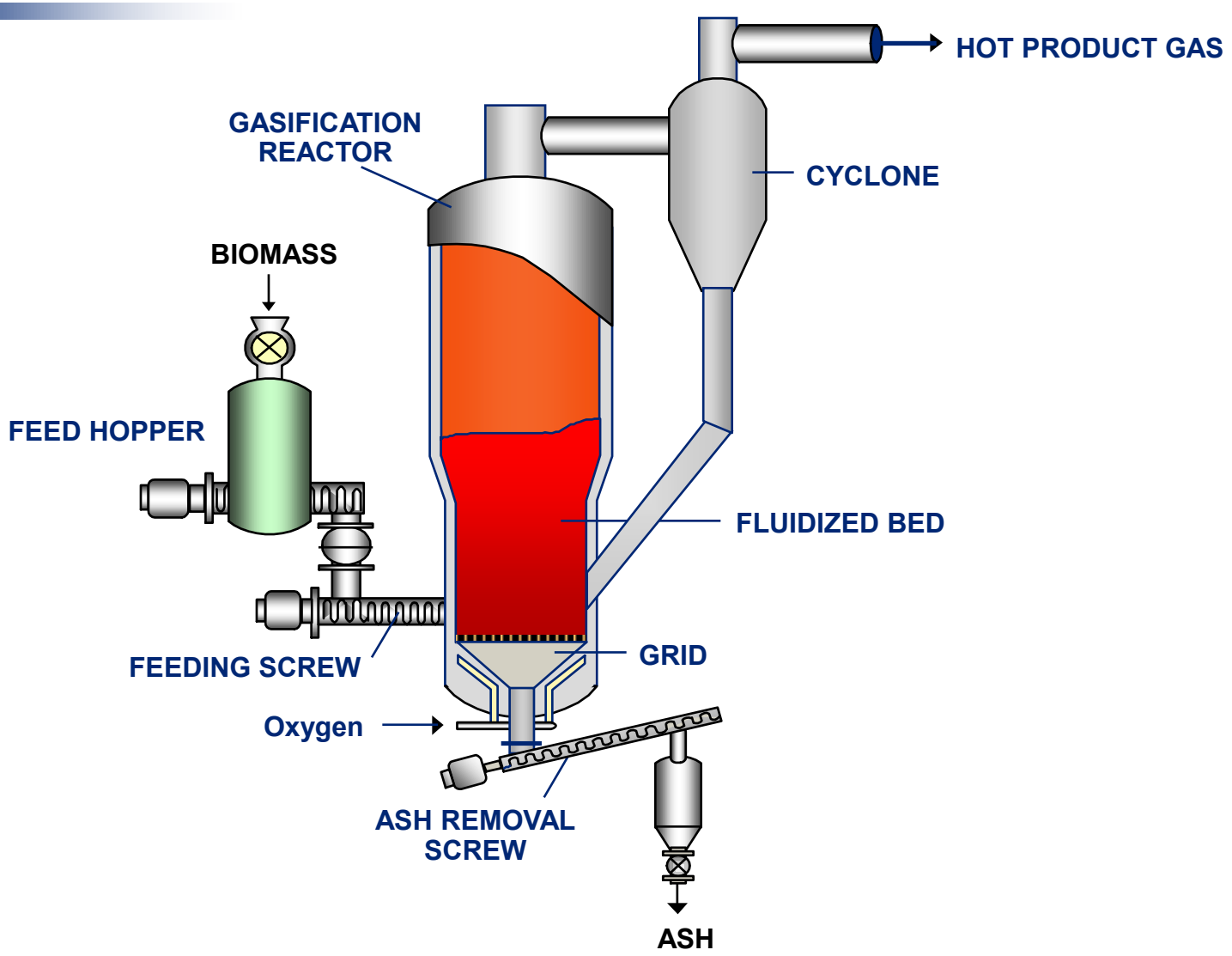
TIGAS skid fabrication at Zeton

Construction at GTI – TIGAS module A1 lift

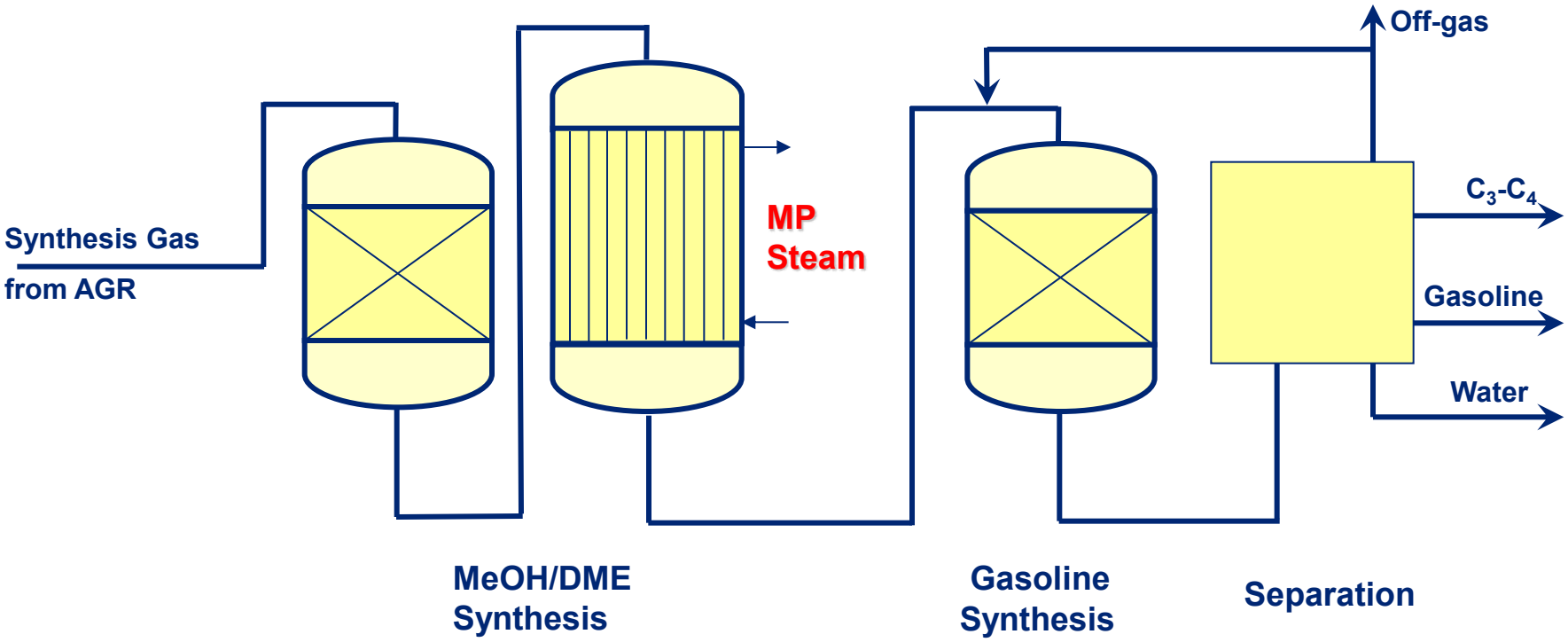
Process flow sheet of demonstration unit



Carbona gasifier



Topsoe TIGAS synthesis



$$CO + 2H_2 = CH_3OH$$
$$2CH_3OH = CH_3OCH_3 + H_2O$$

$$CH_3OCH_3 = 2\text{-}CH_2\text{-} + H_2O$$

Shakedown testing

- Conducted 3 shakedown tests
- Stepwise full-scale operation of each major plant section at process conditions:
  - Gasification section (Nov 2012)
  - Gasification + AGR sections (Dec 2012)
  - Gasification + AGR + TIGAS (Jan 2013)
- Final commissioning of feedstock delivery system, CO_2 supply and purge system, syngas compressor, AGR upgrades, and TIGAS plant operation
- Total 200 hours of gasification, 103 hours AGR, and 56 hours TIGAS operation
- First gasoline production (100 gal)

Test #1 (March 5 - 22, 2013)

- Successful processing of wood feedstock from bulk trucks, to storage silo, and through the pressurized metering system into the gasifier at >75% capacity throughout the test
- Stable, steady-state wood gasification at >75% capacity with 95% carbon conversion to syngas
- Operation of tar reformer at varying conditions to optimize tar and hydrocarbon reforming, H_2:CO ratio, and energy efficiency
- Reliable startup and sustained operation of syngas compressor at >75% design rate
- Reliable AGR system extended operation, delivering decarbonized syngas at >75% capacity
- Sustained 96% CO_2 capture from syngas with Morphysorb® solvent

Test #1 (continued)

- 99.9%+ methanol conversion in TIGAS section
- Produced gasoline-range product at steady-state conditions for a total of 47 hours
- Produced 13.6 bbl of product
- Gasoline octane consistently above target
- Identified key steps to improve performance in next test
  - Hot gas filter durability and stability
  - Naphthalene control with stable catalyst performance
  - Minimization of N_2 in syngas
  - Recycle of tail gas to gasification section
  - Optimization of TIGAS section conditions (P, T, internal recycle)

Test #1 technical data

Syngas production and cleanup (entire test)	
Total biomass fed (6% moisture)	212 tons
Biomass feed rate	1450 lb/h
Hours of operation	
Gasification	299 hours
TAR reformer	299 hours
Compressor	222 hours
AGR	215 hours

Front-end of the demonstration plant to produce clean syngas operated very well and was on stand-by for several days in readiness to provide syngas to the TIGAS synthesis section of the plant.

Test #1 technical data (continued)

Integrated TIGAS operation periods	
Total biomass fed (6% moisture)	34 tons
Biomass feedrate	1450 lb/h
Hours of operation	
TIGAS unit	56 hours
Gasoline production Period 1 (03/12-13)	9 hours
Gasoline production Period 2 (03/18)	15 hours
Gasoline production Period 3 (03/21-22)	23 hours
Total gasoline production time	47 hours
Gasoline produced	573 gal (13.6 bbl)
Octane number (R+M)/2	96.3

After initial mechanical start-up issues the TIGAS synthesis section of the demonstration plant operated very well at steady reactor temperature profiles

Test #2 (October 18 – November 1, 2013)

- Operated the integrated demonstration plant at up to 100% load
- Verified successful performance of the new hot gas filter and other minor modification introduced post Test #1
- Conducted the Independent Engineer (IE) Test
- Introduced syngas recycle to gasifier to maximize yield
- Produced TIGAS gasoline for the emission test at SouthWest Research Institute in San Antonio, Texas

Test #2 technical data

Syngas production and cleanup (entire test)	
Total biomass fed (6% moisture)	182 tons
Maximum biomass feed rate	1689 lb/h
Hours of operation	
Gasification	248 hours
TAR reformer	248 hours
Compressor	235 hours
AGR	235 hours

Front-end of the demonstration plant to produce clean syngas operated very well and produced syngas for TIGAS unit within specifications

Test #2 technical data (continued)

Integrated TIGAS operation periods	
Total biomass fed (6% moisture)	150 tons
Maximum biomass feedrate	1689 lb/h
Hours of operation	
Gasoline production Period 1 (10/22-26)	73 hours
Gasoline production Period 2 (10/27 -11/01)	121 hours
Total gasoline production time	194 hours
Gasoline produced	3954 gal (94.1 bbl)
Octane number (R+M)/2	>90

The TIGAS synthesis section operated very well at steady reactor temperature profiles, stable product distribution, very low methanol slip, and an increasing gasoline yield

Independent Engineer (IE) Test

Objectives:

- Demonstrate that all of the instrumentation and analytical equipment is in place and operating satisfactorily – *PASSED*
- Demonstrate that all of the mechanical, electrical and environmental control systems are complete and capable of operating safely and within the permit limitations – *PASSED*
- The facility has operated continuously throughout the IE Test at a minimum average feed rate of 1,430 lb/h of wood pellets for 72 hours – *PASSED (actual was 1,601 lb/h)*
- The product gasoline produced during the IE Test is a liquid hydrocarbon product in 4 to 12 carbon range with a minimum average of research and motor octane ((R+M)/2) of 83 – *PASSED (actual average was 90.2)*
- The methanol content of the water condensate produced during the IE Test is less than one weight percent – *PASSED (actual was 0.0106 wt-%)*

During the IE Test the plant produced about 1700 gallons of gasoline

Test #3 (March 3 –16, 2014)

- Operated the integrated demonstration plant at up to 100% load with recycle.
- Produced more than 8000 gallons of TIGAS gasoline for the fleet test at test site in Ohio

TIGAS gasoline testing

- Engine emissions testing at SwRI
  - Tested a 80/20 high biomass TIGAS/gasoline blend
  - Emission level better than conventional gasoline
  - Phillips 66 will prepare EPA application for this blend

- Moderate Fleet Testing (planned for spring/summer 2014)
  - 8 vehicles over ~ 4 months
  - Accumulate ~ 600,000 miles

NACE corrosion test

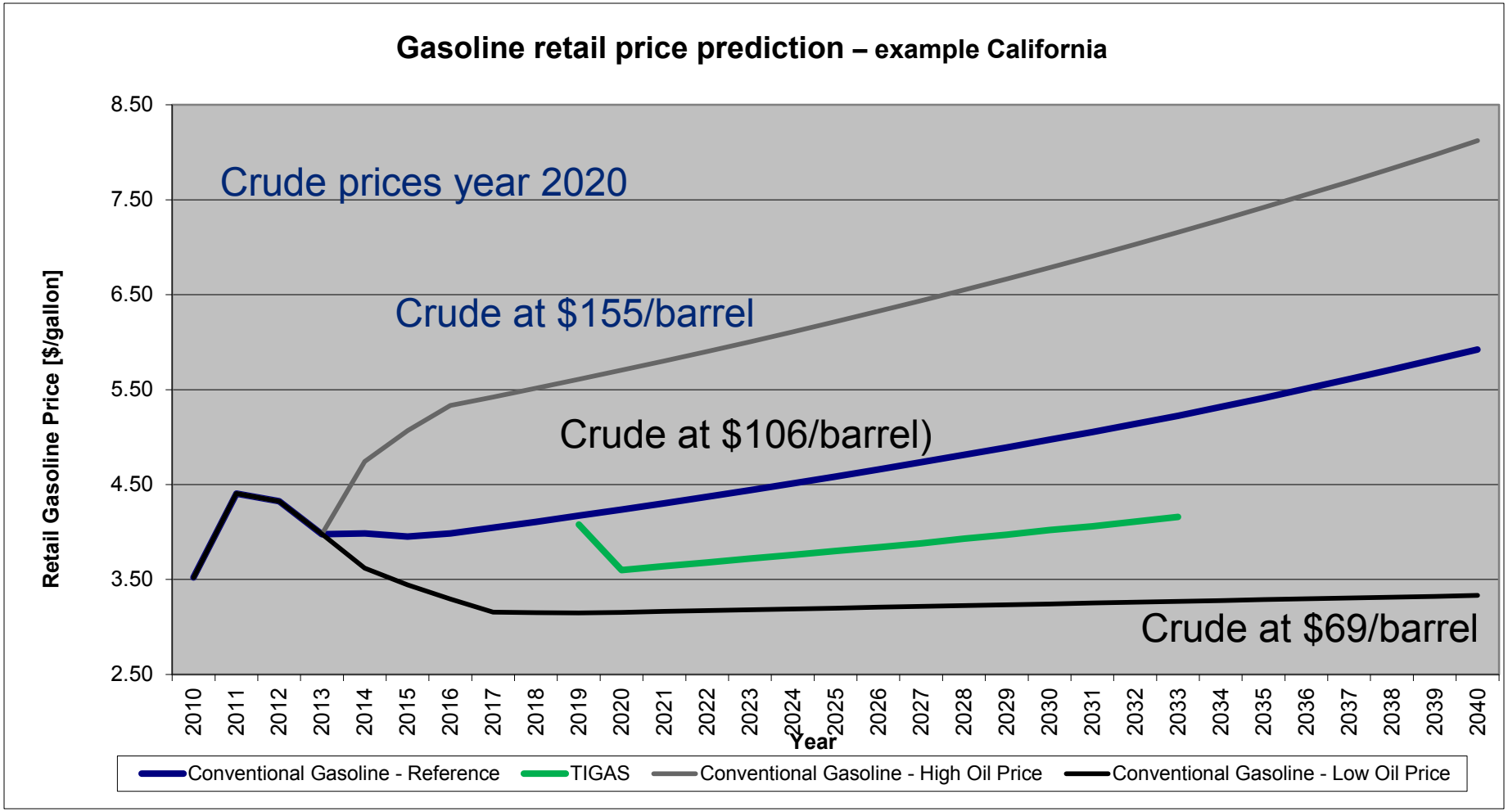
- Innospec Fuel Specialties performed corrosion evaluation of the raw TIGAS gasoline product using the NACE TM01-72 Corrosion Test.
- With a low treat rate of 2 ptb DCI-6A the raw TIGAS gasoline meets the typical Pipeline Specification of B+ (<5% corrosion).
- The actual test data showed much less corrosion corresponding to a B++ (<0.1% corrosion).
- A blend of the raw TIGAS gasoline and ethanol (E10 Blend) meets the B+ rating even before adding any corrosion inhibitors.

Process efficiency in commercial plant

- Energy efficiency*
  - 45% input energy (biomass) converted to finished products (gasoline + LPG)
- Carbon efficiency*
  - 32% input carbon (biomass) converted to finished products (gasoline + LPG)

** Based on original proposed design basis*

Project economics



Source: AEO2013 - Report Number DOE/EIA-0383(2013) http://www.eia.gov/forecasts/aeo/

Areas for further development & demonstration

1. Total installed cost
    - Processing biomass is more expensive than using natural gas
    - Consider co-feeding biomass and natural gas (shale gas)
2. Optimization of the biomass gasifier system
3. Optimization of gas recycling
    - Back to gasifier for conversion of hydrocarbons
    - Back to Methanol/DME reactor for increased conversion of syngas
4. Continued optimization of catalysts
    - Increased yield and selectivity
    - Increased resistance towards poisoning (deactivation)