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California Energy Commission
Docket Office
ATTN: Docket 06-AFP-1
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512
Via email to docket@energy.state.ca.us

RE: Docket No. 06-AFP-1 Alternative Transportation Fuels Plan
Full Fuel Cycle Assessment

Dear Sir/Madam:

Attached please find Shell Oil Company's comments concerning TIAX's "Full Fuel Cycle Analysis Assessment" (CEC publication numbers: CEC-600-2007-002-D, CEC-600-2007-003-D, and CEC-600-2007-004-D).

Shell has extensive experience with Well-to-Wheel (WtW) analysis in both Europe and the U.S. This experience has given us several insights into the WtW methodology, its limitations and situations in which it may be usefully applied. While we appreciate that TIAX has expended considerable effort in the development of the draft report, our analysis indicates that much more work remains to be done. As discussed in more detail in the attached comments, we have identified significant parts of the TIAX report that should be revisited and revised before the report is finalized.

Shell appreciates this opportunity to submit comments concerning the draft report. We would welcome the opportunity to discuss our comments further with CEC staff and the report authors. In the meantime, should you have any questions concerning our comments, please let me know.

Sincerely yours,

Barbara Kornylo
BK/rmf

cc: Tim Olson

Shell Global Solutions

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UNRESTRICTED

Review of TIAX LLC's WtW Study of Alternative Fuels & Vehicles

Shell Global Solutions

GS.07.50721
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Review of TIAX LLC's WtW Study of Alternative Fuels & Vehicles

by

Shoba Veeraraghavan
Karen Lee
King Eng
Roger Cracknell

UNRESTRICTED

Summary

Royal Dutch Shell has been active developing and applying the "Well-to-Wheel" or "Full Fuel Cycle Analysis" approach for comparing the greenhouse gas emissions impacts of alternative fuel and powertrain choices. Shell's extensive experience with WtW analysis in both Europe and the US has given us several insights into the WtW methodology, its limitations and situations in which it may be usefully applied. A WtW analysis must be based on sound science and defensible methodology. The analysis is highly complex and requires numerous assumptions and inputs which together determine the final outcome. Therefore precision, completeness and representativeness of the data must be addressed, as also the consistency and reproducibility of the methods as well as the data sources.

We have reviewed TIAX LLC's three reports and supporting spreadsheets[1] used in the development of their Well-to-Wheel analysis of fuel/vehicle systems in California. Six key areas of concern are identified:

1. Lack of Transparency and Consistency in Analysis
Our ability to analyze the TIAX report is significantly hindered by the lack of transparency in the report. The report is very general and often lacks specifics. The results are not transparently and straightforwardly derived. We found it very difficult to track calculations from inputs and assumptions to final results even with the help of the TIAX spreadsheets. For example, different sections contradict one another, tables and figures are not always in the relevant place in the text and do not always describe the same pathways. The approach adopted in the JRC-EUCAR-CONCAWE, or JEC, study (clear description of methodology and data inputs including tables; unique codes and graphical depiction of all pathways; extensive tabulation of Well-to-Tank, Tank-to-Wheel and Well-to-Wheel energy consumption and emissions by pathway) would serve as a useful reference.

2. Marginal Approach
TIAX assume that the extent of substitution of refinery fuel products by alternative fuels is small, and use a marginal approach to simplify the calculation of GHG emissions from refinery fuels, although it is not clear how marginality is operationalised in the TIAX analysis and whether this is done correctly and consistently. This approach is appropriate in the short term when there is limited substitution of conventional fuels by alternatives, but there should be due consideration of the longer term when the marginal assumptions may no longer be valid. If the marginal approach is retained, it should be substantiated with results from refinery modelling as well as modelling of other marginal assumptions.

3. Use of GREET 1.7
The GREET software[2] is used by TIAX to calculate the WtW emissions of each feedstock-manufacturing process-fuel product-vehicle pathway GREET was never intended as a

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[1] Unnasch et al (2007a) "Full Fuel Cycle Assessment : Well to Tank Energy Inputs, Emissions and Water Impacts" CEC-600-2007-002-D; Unasch et al (2007b) "Full Fuel Cycle Assessment : Tank to Wheels Emissions and Energy Consumption" CEC-600-2007-003-D; and Unnasch et al (2007c) "Fuel Fuel Cycle Assessment : Well to Wheels Energy Inputs, Emissions, and Water Impacts" CEC-600-2007-004-D; spreadsheets downloaded from ftp://ftp.arb.ca.gov/carbis/fuels/ab1007/ca_greet/

regulatory tool but rather as an input into scenario analysis. Therefore, careful consideration must be given on the appropriate use of the TIAX report in regulatory development.

4. Treatment of Coproducts

TIAX do not discuss how they handle emissions from the marketable coproducts which are typically produced along with the alternative fuel of interest during the manufacturing stage. They appear to have used both the emissions-credits-via-substitution (also known as displacement) method and the emissions allocation method for coproducts : for example, substitution for soy biodiesel coproducts, but allocation for forest residue-derived ethanol coproducts. Consistency in approach is important because the WtW emissions of alternative fuels pathway depend critically on how coproducts are treated. Where possible, substitution is preferable because it relates directly to net GHG benefit. TIAX should apply one method only and apply it consistently.

5. Excluded Pathways

The TIAX reports suggest that a large number of feedstock-fuel pathways have been evaluated but presents results only for a few. Of these pathways, several are inadequately treated. Some of their Well-to-Tank and Well-to-Wheel emissions results do not agree with results from other reputable studies. For example GTL WtT emissions are significantly higher when compared against the JEC study while CNG emissions are low. Potentially important fuel pathways in the 2020 timeframe such as cellulosic ethanol via enzymatic hydrolysis, hydrotreated vegetable oils, renewable hydrocarbons via the Lurgi process (MtSynfuels), hydrogen from Natural Gas in an integrated LNG/Central H_2 processing facility and pathways incorporating Carbon Capture and Storage have not been considered.

6. Multimedia Impacts and Land Use Change

It does not appear that multimedia impacts of petroleum fuels and bio/synthetic fuels have treated similarly, since impacts of the latter have generally been ignored on the rationale that they will be produced outside the state. This can lead to a distorted ranking of the environmental impact of the alternative pathways on offer, as well as a false assurance that an increase in biofuel farming in California or elsewhere has no adverse impact on the environment and ignores, among other things, the substantial impact that agriculture run-off has on water levels and quality. loss in biodiversity, and land use change impacts.

In sum, while it is apparent that TIAX has invested significant effort in the generation of these reports, much work remains to be done. As discussed in more detail in the following pages, we have identified significant parts of the TIAX analysis that should be revisited and addressed before this report is finalised.

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[2] Developed and updated periodically by Michael Wang of Argonne National Laboratory. Current version of the GREET model is version 1.7, which is also the version used in the TIAX analysis. The TIAX implementation of GREET which is available from the CEC website is the file "greet1.7row_us_ca_v53.xls"

Review of TIAX LLC's WtW Study of Alternative Fuels & Vehicles

1. Introduction and Background

1.1 Shell Experience in Well-to-Wheel Analysis

Royal Dutch Shell has been active for several years in developing and applying the "Well-to-Wheel" or "Full Fuel Cycle Analysis" approach for comparing the GHG emissions impacts of alternative fuel and powertrain choices. We have participated in several major studies.

- The General Motors – Argonne study of advanced North American fuel/vehicle systems in 2001 and in 2005.
- The General Motors – L-B Systemtechnik study of advanced European fuel/vehicle systems in 2002.
- The EU Joint Research Centre-EUCAR-CONCAWE analysis (JEC study) of current and future fuel/vehicle systems between 2003 and 2006. CONCAWE is the European oil companies' environmental advisory group, while EUCAR represents European vehicle manufacturers. This is an ongoing effort involving one of the authors (RC).
- Several studies specific to GTL fuel have been commissioned by Shell, in some cases jointly with SASOL Chevron and Conoco Philips. These have been conducted by Price Waterhouse Coopers and J. Thijssen.

1.2 California's Low Carbon Fuel Standard

The California Energy Commission, the Air Resources Board and the University of California are developing a "Low Carbon Fuel Standard" for transportation fuels following the Governor's directive[3] in early 2007. The standard would be consistent with Assembly Bill 32 which commits the state to reducing statewide GHG emissions to 1990 levels by 2020. This is equivalent to a 10-20%[4] reduction relative to a Business-as-Usual (BAU) level of emissions, with annual reductions on a sliding scale leading up to the 2020 target. Implementation of the standard will commence by or before 2010.

The LCFS is to be based on a Full Fuel Cycle Analysis, i.e. on WtW emissions. The State has published a White Paper[5] which provides background information on how the standard will be implemented and scenario analysis to suggest how the standard could be met.

It is not clear whether WtW or WtT emissions will be regulated through the LCFS. The metric described in the White Paper, namely gCO_2e per MJ[6], could refer to either WtT or WtW

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[3] Executive Order S-01-07: Low Carbon Fuel Standard.
[4] Range of values noted from different projections. The 10% reduction by 2020 mentioned in the Executive Order does not provide the baseline against which this reduction is to be made.
[5] D. Crane and B. Prusnek (2007), "The Role of a Low Carbon Fuel Standard in Reducing Greenhouse Gas Emissions and Protecting our Economy"
[6] Greenhouse gas emissions measured in grammes of CO2-equivalent per MJ of fuel energy. The emissions from GHGs other than CO_2 are expressed in equivalent weight of CO_2 . In keeping with international practice, we use metric units, rather than the British units which are prevalent in California.

emissions. The Paper is confusing in its language : it describes "Full Fuel Cycle" as WtW (and "field-to-wheels" for biofuels) but later goes on to say that this includes only upstream feedstock extraction, fuel refining, and transport to market (thus excluding vehicle emissions). This is explained as necessary to avoid double-counting of vehicle emissions which are already regulated under AB 1493[7] vehicle standards.

It is also not clear which vehicles uses will be regulated through the LCFS. The LCFS Executive Order applies to transportation fuels (without further qualification) whereas the White Paper implies that the standard will be limited to road transportation fuels used in passenger vehicles.

2. General Comments on WtW analysis

Shell's extensive experience with WtW analysis has given us several insights into the WtW methodology, its limitations and situations in which it may be usefully applied.

A WtW analysis is effectively a limited lifecycle analysis which considers only the GHG emission and energy consumption impacts of a fuel product. A complete lifecycle analysis looks at the total environmental impact (including non-climate related impacts) of a fuel product during its production, use and disposal. The impact derives from material and energy flows and emissions during the production of vehicles and fuel supply infrastructure, the production and use of the fuel, and the dismantling of the fuel infrastructure and disposal of vehicles. The justification for excluding the vehicle & fuel supply infrastructure aspects (so-called grey energies) in the WtW analysis is that they typically have a small impact. There is also the pragmatic reason that good data on grey energies are usually lacking.

A choice which has to be made before beginning a WtW analysis is whether to follow the ISO 14040 series guidelines on conducting lifecycle analysis and to what extent. Most of the well known WtW analyses follow ISO in spirit rather than to the letter. The guidelines that are followed include a clear definition of the goal, scope, and the target audience in the analysis, a clear description of the product system under study, use of the same methodology to compare systems and adequate stakeholder consultation. Deviations from the guidelines are typically in the non-inclusion of grey energy (recommended by ISO guidelines but not included for reasons mentioned earlier) and in the distribution of emissions from fuel production processes among the multiple product streams - some applications of ISO guidelines could lead to unmanageably large system boundaries while obscuring the systems actually being compared.

A WtW analysis must be based on sound science and defensible methodology. The analysis is highly complex and requires numerous assumptions and inputs which together determine the final outcome. Therefore precision, completeness and representativeness of the data should be addressed, as also the consistency and reproducibility of the methods as well as the data sources. Sound inputs, as well as acknowledgement of any inherent variability or error in the inputs, are critical to a credible outcome. Several inputs to the WtW analysis are probabilistically distributed (e.g. natural gas composition), inherently variable (e.g. biofuel crop yield), poorly characterised (e.g. site dependence of nitrous oxide emissions from biofuel crops) or suffer from variable data quality. The uncertainties should be addressed via probability distributions and establishing confidence ranges, as also sensitivity analysis. We point to the JEC and GM-Argonne studies as examples of good practice in this respect. Any

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[7] Assembly Bill 1493 (passed 2005) regulates vehicle emissions beginning with model year 2009. It is expected to reduce vehicle emissions by 17% by 2016 and 27% by 2030.

attempt to shrink the entire analysis of a fuel lifecycle down to a single carbon intensity[8] number should be viewed with caution.

A WtW analysis is specific for a geographical region and time period. For instance the primary fuel mix for power generation varies with region; manufacturing efficiencies improve with time and technology maturation; vehicle fuel efficiency is evolving. Thus a result derived for one region and time cannot be carried over to other regions or times. (However, relative WtW impact of similar fuel/vehicle pathways is often similar and can, with experience, be compared across locales and dates).

A WtW analysis on its own does not predict environmental outcomes except in the limited sense of comparing the GHG emissions impact of similar fuel pathways at a given moment in time. Other factors such as policies, regulations, fuel demand and supply, prices and consumer choices typically have greater influence. That said, a WtW comparison can be very useful in comparing the GHG impact of alternative feed-process-fuel-vehicle systems, and in ranking broad classes of fuels in terms of their contribution to sustainability provided all the caveats discussed so far inform the use of the WtW analysis. This was the approach taken in the JEC and GM-Argonne studies.

3. Review of the TIAX WtW analysis

We have reviewed a WtW analysis of several alternative fuels and vehicles carried out by TIAX LLC on behalf of the CEC. The analysis, which is described as California-specific, is documented in three reports and is supplemented by spreadsheets available on the CEC website. The TIAX analysis was originally intended to assist CEC in comparing different transportation fuel scenarios in the period from 2012 to 2030 and to help it in preparing an Alternative Fuels Plan by mid-2007 as required by AB 1007. We understand that the TIAX analysis will now be used in developing the LCFS, although it is not clear how this will be done. A major issue is that the WtW calculations were designed for use in future scenario analysis rather than for regulatory purposes, and even if these are considered suitable for regulatory use, they will still have to be modified post facto to enable such application.

We've looked at the TIAX reports specifically from the viewpoint that these reports might soon be "frozen" and used "as is" in developing the LCFS. Our conjecture is that there are two possible applications : conversion of WtW results into carbon intensity factors for each fuel or pathway which will be applied to all fuel suppliers, or establishment of a methodology (the TIAX methodology) by which each supplier will be expected to calculate their carbon emissions using supplier-specific data possibly supplemented by verifiable measurements. Thus we've scrutinised the report on two counts : whether the carbon factors are consistent with other analyses and derived using a sound methodology, and whether the methodology transparent, straightforward and applied similarly for all pathways. We've also considered what needs to be done to improve the analysis, both for use in the LCFS and for the original scenario analysis reasons (AB 1007).

A very large number of pathways are considered by TIAX, as well as multiple impacts – greenhouse gases, criteria pollutants, multimedia impacts – but a very short time period has

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[8] The carbon intensity in a WtW context is the total GHG emissions from all stages in the fuel lifecycle from feedstock production to combustion in the vehicle for an appropriate unit measure of utility: this could be the fuel energy content or the distance driven. WtW intensities for these two different utilities are gCO_2e/MJ and gCO_2e/km respectively, and the latter depends on the vehicle fuel efficiency. Other metrics for carbon intensity such as the fuel heating value (MJ/kg) or biofuel content do not accurately describe the WtW impact of the fuel.

been available for review and comments before the reports "freeze". Therefore we have been unable to carry out an in-depth analysis of every pathway, or test all the input data or results presented.

Our approach has been to focus on a selection of pathways, particularly where comparison with the JEC study is possible. This major European study was recently updated and is relatively credible as it represents the consolidated output of a wide range of stakeholders. We tested these sample pathways on whether they meet the criteria for a "good" WtW analysis. This has brought up several issues of major concern which must be addressed prior to using the work in developing the LCFS or for any other material purpose. There are likely to be additional issues which we have not had time to identify and address in this written statement.

Although the TIAX reports consider both light and heavy duty uses of fuel products (passenger and freight applications) we have mainly focussed on passenger vehicle applications for simplicity given the limited time for review, on the reasoning that this restriction will not affect the relative performance of different fuels.

We have not looked at emissions arising from feedstock or fuel transport in the short time provided since these typically are only a small fraction of the total WtW emissions in most pathways. An exception is remote compressed natural gas where transport is known to have a significant impact on WtW GHG emissions (see the JEC study WtT report for a discussion). Similarly we have addressed mainly GHG emissions performance but also criteria pollutant emissions to some extent. The first of the TIAX reports contains WtT GHG emissions (using the metric gCO_2e/MJ). The next two reports consider TtW emissions and the integrated WtW emissions respectively, and use the metric gCO_2e/km[9].

We have treated the TIAX written reports as the primary output of their analysis and the spreadsheets only as an aid to better understanding where the reports are unclear.

The rest of this report discusses findings from our review of the TIAX study as a potential basis for developing the LCFS. Section 3.1 below lists findings which are common to all three reports (WtT, TtW and WtW) . Sections 4, 5, and 6 present our views on each of the individual reports.

3.1 Overview

The usefulness of TIAX report is compromised by a number of serious shortcomings. For example - different sections contradict one another, tables and figures are not always in the relevant place in the text and do not always describe the same pathways. The overall impression is of a set of documents which have been written without due consideration for consistency, logic or coherence, and it is difficult to assess whether these failings are confined to the written report or also apply to the bulk of the calculations which are presented therein. All three reports and the spreadsheets suffer from these inadequacies. This has made it difficult to quantitatively compare the TIAX results with results from JEC and GM-Argonne studies.

The reports suggest that a large number of feedstock-fuel pathways have been evaluated but present results only for a few pathways. Feedstock-fuel pathways are not clearly described or graphed anywhere therefore it is impossible to work out which pathways were evaluated. This is to be contrasted with the detailed tabulation in the GM-Argonne Study and the

[9] In fact the metric used is $gCO_2e/mile$ but we use metric units for consistency throughout this text.

graphics and tables in the JEC study. The spreadsheets accompanying the reports do not lay out which pathways were evaluated, the timeframes, or the data inputs. Therefore these spreadsheets have proved to be of very limited value.

Data quality and error estimation have not been addressed anywhere in the report. Nor is there a sensitivity analysis.

The analysis is said to cover the multiple years 2012, 2017, 2022 and 2030, but most of the results presented refer to 2012.

TIAX conclude with three lists of feed-fuel pathways which are ranked by carbon intensity on a Well-to-Tank and Well-to-Wheel basis for light duty vehicles and on Well-to-Wheel basis for heavy duty vehicles. This ranking is not supported by the limited results presented elsewhere in the reports.

4. Review of the Well-to-Tank Report

We have found problems with the WtT analysis carried out by TIAX along three key dimensions: presentation, methodology and results/treatment of individual pathways. **Section 4.1** contains an overview of these issues which are then explained in detail in **Sections 4.2, 4.3** and **4.4**.

4.1 Main Issues with TIAX WtT Analysis

Presentation of the WtW Analysis

There are some consistent themes with respect to the way in which the report has been put together. These issues must be addressed before the analysis is "frozen" for purposes of the LCFS because they are fundamental to the integrity and credibility of the analysis:

> **Lack of Transparency and Consistency in Analysis :** The report is very general and often lacks specifics. The results are not transparently and straightforwardly derivedWe believe that this is not just due to poor reporting quality but reflects a need to improve the underlying analysis itself. Some examples are provided in ***Section 4.2.1***.
>
> **Consideration of ISO 14040 Series Guidelines :** While we do not insist that the report should be compliant with every detail of the ISO 14040 series guidelines for the reasons discussed in Section 1.2, it does seem that the report would have benefited from consideration of these guidelines. This is discussed in ***Section 4.2.2.***

WtT Methodology Employed by TIAX

There appear to be methodological issues with the analysis which should be dealt with prior to its use in developing a regulatory standard:

> **The Marginal Approach :** This assumes that the extent of substitution of refinery fuel products by alternative fuels is small, and is used to simplify the calculation of GHG emissions from refinery fuels and we agree that this is appropriate in the short term. However the state ultimately aspires to reduce statewide GHG emissions considerably more (by 80% relative to 1990 levels in 2050). If this were to be achieved by a substantial decrease in gasoline & diesel volumes for road transport, then these fuels will then no longer be the dominant fuels in the market. The marginal approach will not be applicable over such a range in emissions reductions. There will have to be an alternative means of calculating refinery product emissions in later years, and there must be a smooth transition from the marginal calculation to this alternative calculation. This issue deserves to be properly discussed in the report.
>
> It is not clear how marginality was operationalised in the TIAX analysis and whether this was done correctly and consistently. These issues are discussed in **Sections 4.3.1** to **4.3.5**.
>
> **Treatment of Coproducts :** TIAX do not discuss how they handle emissions from the marketable coproducts which are typically produced along with the alternative fuel of interest during the manufacturing stage. They appear to have used both the emissions-credits-via-substitution (also known as displacement) method and the emissions allocation method for coproducts. As far as possible, a common methodology should be employed with respect to coproducts. This is discussed in **Section 4.3.6.**

Application of the MathPro Refinery Model: The MathPro refinery LP model was used to calculate refinery efficiencies but the report does not clearly specify what assumptions went into the refinery model. This is discussed in **Section 4.3.3**.

Impact of Crude Variability on In-State Refining Emissions : The differential impact of variability in crude feedstock on refining emissions is small can be ignored for simplicity. This is discussed in **Section 4.3.4**.

Application of GREET methodology : The GREET software was used to calculate WtW emissions for fuel pathways. It should be borne in mind that GREET was never intended as a regulatory tool but rather as an input into scenario analysis. There are some limitations in the GREET model and issues with the its treatment of particular pathways which are discussed in **Section 4.3.7**.

Multimedia Impacts : Inconsistency in treatment of multimedia impacts of petroleum fuels and bio/synthetic fuels is discussed in **Section 4.3.8**.

Timeframe of the WtW Analysis : The report claims to analyse emissions for multiple years between 2012 and 2030. In fact most of the data presented in the reports refer only to 2012. This and other timeframe issues are discussed in **Section 4.3.9**.

Coverage of Individual Pathways

TIAX is to be commended for the large number of pathways which have been considered. However, TIAX results are also not always in agreement with other analyses even when differences in locale and time are accounted for. Further work is needed in the following aspects :

Treatment of Individual Pathways : The TIAX results do not always agree with results from similar studies but there is insufficient information to understand why. The TIAX findings for a range of fuel pathways are discussed in **Section 4.4.1.**

Missing Pathways/Fuel Options : Several pathways involving fuel products which are available today or which would be available by 2020 are not considered. Neither is carbon capture and sequestration - a viable option for many processes leading to fuel products and can dramatically alter the WtW carbon footprint of many pathways. This has not been considered in the report. These are discussed in **Section 4.4.2**.

Ranking of Fuel Pathways : TIAX have ranked a series of pathways on a WtT basis. This ranking is not completely supported by analysis results and we do not think that it has any meaningful use. This discussed in **Section 4.4.3**.

These issues are now discussed in detail in what follows.

4.2 Detailed Consideration of TIAX Presentation of WtT Analysis

4.2.1 Lack of Transparency and Consistency in Analysis

The report is very general and often lacks specifics. We found it very difficult to track calculations from inputs and assumptions to final results even with the help of the spreadsheets. The evaluated pathways appeared to change randomly over the course of the WtT report, and it was difficult to identify the exact pathways covered.

The lack of properly tabulated results also prevented a thorough review of the TIAX analysis, as the necessary data for consideration were simply not available. The approach adopted in the Concawe study (clear description of methodology and data inputs including tables; unique codes and graphical depiction of all pathways; extensive tabulation of Well-to-Tank, Tank-to-Wheel and Well-to-Wheel energy consumption and emissions by pathway) could serve as a useful reference.

The study covers some alternative fuels used in blended form (E10, E85 and FTD30). TIAX has compared the GHG impact of the blends to the corresponding refinery fuel being substituted. In addition to this, providing results for the pre-blended components (e.g. 100% ethanol) would clarify the distinction between different production pathways for the same alternative fuel (e.g. bioethanol from corn, sugar cane and cellulose). This was found to be helpful in understanding the results of the JEC study.

Some examples of inconsistent presentation in the TIAX WtT report are listed below. This is in no way a complete list :

Section	Page	Issue
1.1	1-3	Names listed here for the 3 report volumes don't match actual titles
2.2.2	2-8	Says that fuel properties whose values in GREET were changed are listed in Section 1-3 (which actually lists WtT report chapters)
1.2 & 2.2.2	1-4 & 2-4	Petroleum (crude oil) listed as sole feedstock for RFG-E5.7 and E10 in Tables 1-1 and 2-3, which ignores ethanol production. Ethanol only listed as E85 and E-diesel
1.2 & 2.2.2	1-4 & 2-4	Tables 1-1 and 2-1 both list fuel-feedstock combinations evaluated but they don't have exactly the same combinations, e.g. DME and methanol from coal & biomass suggested only in Table 1-1. Electricity & H2 not included in Table 2-1. Table 2-3 of the WtW report is yet another such list. *We suggest that flow diagrams be included which fully cover all pathways evaluated*
2.2.5	2-12	Table 2-3 poorly labelled & described and not related to surrounding text. We think that it is actually a continuation of Table 2-1
3.1.1	3-3	Spurious title "Effect of ethanol blends" has appeared from nowhere

4.2.2 ISO 14040 series

While we do not suggest that the analysis should have been conducted strictly as per ISO guidelines, the study authors and the CEC would clearly have benefited by adhering to some of key elements in the guidelines:

- Clear definition of goal and scope - the report is clearly being used outside of its orginal scope if used to inform the LCFS. The product system(s) being studied are not clear since pathways seem to change almost randomly from page to page. Similarly, allocation procedures, assumptions and limitations are not well defined;
- Consideration of comparative assessments, consistency and reproducibility of methods, data sources and their representativeness, uncertainty through probability distributions and confidence levels, and sensitivity analysis. These issues have not been addressed.

As an aside, we note that amongst ISO's recommendations on the uses of LCA, conversion of a lifecycle environmental impact to a single overall score or number[10] (e.g. use of carbon intensity to describe climate impact of a fuel product) which can be used for regulatory purposes is not mentioned.

4.3 Detailed Consideration of Methodological Issues

Most fuel manufacturing produces byproducts in addition to one or more fuel products. Two methods are used to distribute manufacturing emissions between the different products : allocation or system boundary expansion. The second method is commonly used for alternative fuel production but is infeasible for refineries. However for refinery emissions, a marginal approach can be used to sidestep allocation ambiguity.

4.3.1 Marginal Approach

TIAX assume that the replacement of refinery products by alternative fuels is *marginal*, i.e. small, and that the reduction in GHG emissions can be calculated *on the margin.* They further assume that both gasoline and diesel are *imported* into California to meet in-state demand in these fuels, and that reductions in gasoline or diesel demand due to substitution by alternative fuels affect only the volumes of imported fuels rather than California refinery production.

There is no substantial discussion of the validity of the marginal assumption. If mogas demand drops substantially, as could well happen if the use of alternative fuels grows rapidly, then it no longer makes sense to calculate emissions from conventional fuels using a marginal assumption. This issue should be treated in detail in the TIAX analysis and substantiated with results from refinery modelling to illustrate the range of validity of the marginal approach.

4.3.2 Marginal Approach for Refinery Products

TIAX is justified in assuming that marginal gasoline is imported. CEC data do indeed show that the state is short on CARB gasoline (around 6% in 2004) although long overall on all gasoline, and that it imports some CARB gasoline. The supply-demand gap is projected to grow by 30% by 2012, and the TIAX assumption that imports rather than increased in-state refinery production will fill this gap is reasonable.

However, California is long on diesel, producing sufficient CARB diesel (implicitly acknowledged by TIAX on p 7-1) and exporting surplus EPA diesel[11]. Therefore the marginal diesel is likely to be produced in-state, although this situation may change in future if demand exceeds supply. A reduction in diesel demand due to substitution by alternative fuels could result in increased diesel exports or reduced imports in the future and the location and magnitude of marginal diesel emissions would depend on which of these two possibilities is realised.

Furthermore, an increase in diesel demand due to substitution of gasoline could lead to decreased diesel exports, fewer imports, or refinery modifications to increase diesel-gasoline

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[10] ISO 14044 - Environmental management – Life cycle assessment – Requirements and guidelines
[11] CEC publication CEC-600-2007-001

ratio. California refinery emissions may be impacted, whereas TIAX assumes that they will not change.

Lastly, the CEC expects "refinery creep" in California i.e. increase in refinery output, taken to be ~0.5% annually[12]. TIAX does not discuss this issue.

We were also unable to locate TIAX's marginal gasoline refinery and marginal diesel refinery. The TIAX report presents several options:

WtT Section 3.1	Marginal gasoline and diesel are imported from unspecified location
WtT Table 2-1	Singapore & California are refinery locations for CARBOB, RFG and ULSD
WtT Sections 7.1.1, 7.1.3	CARBOB & ULSD imported from Middle East refineries

We suggest that CARB gasoline-capable refineries in other US states, Europe, Canada, and the Caribbean should be included in the marginal gasoline refinery, to the extent that gasoline could be imported from these sources.

4.3.3 Refinery Modelling - Use of MathPro

TIAX appear to have used the MathPro refinery model[13] for gasoline and diesel emissions. But many issues remain unclear :

1. The parameters of the marginal gasoline refinery – the MathPro refinery used appears to be a *California-aggregate* refinery used for MTBE phaseout analysis (Section 3.1.1, Ref. on p 9-4). Does this refinery adequately describe refineries from where the marginal CARB gasoline will be sourced ?
2. The parameters of the marginal diesel refinery – it appears to be the MathPro refinery used for PADD 1,2,3 analysis for the EMA (Section 3.1.1, Ref on p 9-4), i.e. outside California
3. Did MathPro employ a marginal refinery calculation to separately obtain the emissions from gasoline and diesel refining ? This is how JEC sidestepped the allocation issue. Table 3-1 suggests that an allocation methodology was instead used, however Tables 7-1 suggest otherwise. If an allocation scheme was used, was it applied at the refinery process level ?
4. How does the MathPro refinery efficiency depend on refinery configuration – simple, complex, heavy coking, etc.?
5. Does the MathPro refinery efficiency depend on type of crude? If so, what is the range of crudes considered and what factors in the calculation influence the efficiency? How was this analysis validated ?
6. It appears that no provision made for refinery efficiency improvement with time. Historically EU refineries have seen a 1% improvement p.a. in their efficiencies, and Delucchi has noted at least a 0.25% annual improvement in US refineries over several years.
7. WtT Section 7.1.3 says that the fates of residual oil and coke, which are refinery byproducts with market value in their own right, were not analysed. However WtT Section suggests that they were indeed included. Which is correct ?

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[12] CEC 600-2007-001

[13] MathPro is a refinery LP model which, in the context of WtW studies, is used to calculate production energy requirements and carbon efficiencies of refinery products.

We would like to see the inputs, assumptions, refinery parameters and methodology described transparently and consistently. We would also like to review the entire MathPro calculation in order to determine whether refineries have been simulated adequately

4.3.4 Impact of Crude on Marginal Assumptions

An issue which could potentially affect one of the key marginal assumptions (in-state refining emissions levels are steady) is the changing properties of crude oil feedstocks for the state refineries. Californian crude is already heavier than the US and world average. The differential impact of variations in assayable properties of crude on refining GHG emissions is small, and for this reason it is usually assumed in WtW calculations (e.g. JEC and GM-Argonne) that refinery efficiency does not depend on the crude assay. GREET also allows a similar assumption. We think that this assumption is valid and will not introduce significant errors into the marginal calculation.

We note also that the main impact of crude properties on WtTemissions is in the upstream segment rather than in refining.

4.3.5 Other Marginal Assumptions

TIAX's marginal approach also includes assumptions about the source of marginal natural gas (remote), primary energy mix for marginal electricity (natural gas & renewables) which appear reasonable.

The authors have not addressed the question of whether the marginal assumptions about power generation and gasoline are still valid in Case 3 where large numbers of pluggable hybrid electric vehicles entering the market. By 2030, there could be around 4.5 million or more PHEVs in the state (depending on vehicle scrappage rates, this is not discussed). In addition to the additional power generation capacity demand of upto 5 GW, a back-of-envelope calculation suggests a 40-50% reduction in gasoline use among such vehicles (WtW report Table 3-15) could result in a 10% drop in overall gasoline demand.

TIAX also do not consider the marginal impact of land use changes and no explanation is provided. These could be substantial especially if large volumes of ethanol or biodiesel are produced for the Californian market and cannot be ignored. TIAX have argued that US crops will displace other crops rather than expand agricultural land area, and that Brazilian sugarcane is not grown in the Amazon, but have provided no data in support of these claims. Due consideration must be given to mitigation of social and environmental impacts arising from increased demand for bio-components for both gasoline and diesel blending – both from US sources and imports. This has been briefly touched upon in the WtW report, Section 5.1 but there has been no effort within the report to address this issue.

4.3.6 Consistent treatment of Emissions from Alternative Fuels and Coproducts

System boundary expansion and emissions credits for marketable coproducts of alternative fuels which displace a more emissions-intensive product ("substitution" or "displacement" method) have become the norm in WtW analyses in preference to allocation methods. In the substitution method, emissions from alternative fuel production are distributed entirely to the alternative fuel, less any emissions credits (or debits) for coproducts to the extent that they displace another product (at the margin). GREET allows the user to choose between allocation and substitution options, and final results are very dependent on this choice.

TIAX have not included a discussion on coproducts in the report or how they handle emissions from coproducts. They do not seem to have dealt with coproducts in a consistent manner. While there is not enough information in the reports on this issue, the accompanying WtT spreadsheet suggests that they used substitution in some cases e.g. soybean biodiesel coproducts, but allocation in other cases, e.g. forest residue-derived ethanol coproducts. Consistency in approach is important because the WtW emissions of alternative fuels pathway depend critically on how coproducts are treated. Where possible, substitution is preferable because it relates directly to net GHG benefit.

TIAX should use one method only and apply it consistently.

4.3.7 Use of GREET

The GREET software[14] is used by TIAX to calculate the carbon intensity of each feedstock-manufacturing process-fuel product-vehicle pathway, however we have our concerns.

1. Is GREET sufficiently robust, versatile and comprehensive for such a use ? Various reviewers have pointed out deficiencies in the model including the use of low refinery efficiencies - in fact TIAX mention refinery efficiencies of 84.5% (used for CARBOB) and 83.9% (MathPro result) compared with 85.5% in GREET. Their choice of efficiency should be transparently discussed and justified.
1. Several of the pathways used in the TIAX analysis have only placeholder values in GREET 1.7 e.g. FT diesel from biomass (BTL). How were these pathways handled ?
2. All the pathways considered by TIAX (and other studies such as JEC) are not available in GREET to our knowledge e.g. biodiesel from palm oil.
3. GREET defaults assume efficiency improvement with time only for some fuel manufacturing processes e.g. for GTL but not for refineries. Historically EU refineries have seen a 1% improvement p.a. in their efficiencies, 0.25% pa for US refineries[15].
4. A version of GREET modified to better represent California appears to have been developed by TIAX. We are unsure if this is refers to the WtT spreadsheet (and WtW post-processor) available on the website, since it does not appear to be adequate or complete. It is also not fully documented .

4.3.8 Multimedia Impacts

Several multimedia impacts are listed in Section 6 but only water impacts appear to have been evaluated (Table 6-1) and these are limited to water consumption, wastewater production and hydrocarbons/alcohol discharged into water.

It does not appear that multimedia impacts of petroleum fuels and bio/synthetic fuels have treated similarly, since impacts of the latter have generally been ignored on the rationale that they will be produced outside the state. TIAX have assumed that marginal gasoline and diesel also originate outside California, yet they consider the impact of in-state refining of these fuels. Furthermore, these impacts are assigned to fuel products in proportion to their

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[14] Developed and updated periodically by Michael Wang of Argonne National Laboratory. Current version of the GREET model is version 1.7, which is also the version used in the TIAX analysis. The TIAX implementation of GREET which is available from the CEC website is the file "greet1.7row_us_ca_v53.xls"

[15] M. Delucchi (2003) "A Lifecycle Emissions Model (LEM) : Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials", UC Davis Report UCD-ITS-RR-03-17

volumetric yield (Section 6.2). *Thus there is no consistent methodology of assigning different environmental impacts (GHG emissions & water impact) to fuels.*

TIAX assume that biofuel farming has no multimedia impact because (1) corn and soybean are not grown on irrigated land, and (2) they will not be grown in California in the near future. This can lead to a distorted ranking of the environmental impact of the alternative pathways on offer, as well as a false assurance that an increase in biofuel farming in California or elsewhere has no adverse impact on the environment and ignores, among other things, the substantial impact that agriculture run-off has on water levels and quality (examples of which are discussed in Section 6.3.1!). Loss in biodiversity, and land use change impacts are also not mentioned.

Water impacts do not seem to have been calculated correctly. Figure 6-5 on p 6-7 shows that corn ethanol plants in the Midwest use 4-6 gallons of water per gallon of fuel, yet Table 6-5 on p 6-20 suggests that ethanol uses a staggering 1004 gallons of water/gallon fuel during its lifecycle, while biodiesel water use is 411 gall/gall.

4.3.9 Time series for the pathways

It is not obvious that efficiency gains from technology maturity for fuels, manufacturing and vehicles are properly incorporated. GREET default assumption is that only selected manufacturing technologies improve in efficiency whereas others such as refineries do not. There are insuffiicent data to judge whether TIAX considered these issues. Most of the results in the reports focus on 2012 only, while the study is intended to cover up to year 2030. Time appears to enter into the TIAX analysis only in the sense of changing vehicle emission factors and fuel economy. This is in spite of the reports' stated objective to quantify full fuel cycle emissions and develop emissions scenarios for 2012, 2017, 2022, 2030 and even 2050.

There has been a proliferation of fuel options in the past few years, and this trend is likely to continue into the future. This is not fully reflected in the pathways. TIAX does not appear to have paid sufficient attention to all the pathways of potential within the envisioned timeframe.

AB 1007, AB 32, and the LCFS have their individual defined target years and deadlines, The times analysed in the TIAX work are consistent with AB 1007 times (for obvious reasons). However this makes it more difficult to carry over the TIAX results for LCFS use.

4.4 Detailed Consideration of Fuel Pathways

4.4.1 Treatment of Individual Pathways

Gasoline and Diesel pathways

TIAX may be confusing tar sands (bitumen) with heavy crudes which are conventional crudes with lower API gravity. The heavy crude pathway listed in Table 7-3 does not appear in Figures 7-1 or 7-2 which display energy and GHG results.

We discuss the tar sand results further under Unconventional Crudes.

Also in Figure 7-2, E-diesel is presented with no explanation of what this fuel is or the components, hence it is not possible to judge if the result is meaningful.

Natural Gas Pathways

Here also, the pathways table (Table 7-6) does not contain the same pathways as the graphs of the results (Figures 7-4 to 7-6). CNG from landfill gas and LNG from N American natural gas are missing. Yet the discussion on p7-10 refers to Figure 7-6 and describes landfill CNG as favourable.

The WTT GHG emissions for remote CNG (Figure 7-5) are much lower than what would be expected based on other studies. For remote CNG, transport accounts for the bulk of WTT emissions and therefore has a great influence on overall WTT emissions, yet TIAX results are similar to that from the JEC study, despite a significantly longer transport distance.

	TIAX	**JEC**
Transport distance for remote natural gas (as LNG)	7200 miles	4350 miles (7000 km)
WTT GHG emissions	21.0 g CO_2 eq./MJ[16]	21.7 g CO_2 eq./MJ

Fischer Tropsch Diesels

The GTL pathway was discussed in detail in a separate submission to CEC from Shell in respect of AB1007 (on March 16, 2007), we refer to it for details of our concerns regarding treatment of GTL fuels. Here we only comment on a couple of points :

- TIAX assumes that all synfuels are produced from natural gas in Indonesia and shipped to California (Section 3-4). In fact, large-scale GTL plants are being constructed in the Middle East by Shell, Chevron and others, utilising nearby natural gas resources. Within the time frame considered in the study, a larger proportion of GTL is likely to originate from the Middle East than from Southeast Asia
- The WTT emissions associated with GTL appears to deviate significantly from that published in other studies which use the same overall GTL plant efficiency (63%). The disparity cannot be explained away even if we allow for the larger GTL transport distance from Malaysia to California in comparison with the Middle East to Europe.

	TIAX *(GTL from Malaysia to CA)*	**JEC** *(GTL from ME to Europe)*
WTT GHG emissions	32 g CO_2 eq./MJ[17]	25.1 g CO_2 eq./MJ

We could not ascertain whether TIAX examined synthetic Fischer-Tropsch fuels from feedstocks other than natural gas. We quote, "Although there are other feedstocks of interest, such as coal, biomass and landfill gas, there are not considered commercially viable and are not analysed here" (Section 3.4).

However, TIAX has listed assumptions for CTL and BTL pathways (Table 7-9) and has also included CTL in its ranking of GHG impacts (Section 8) although they present no CTL results in Section 7.

This is potentially a serious omission since both coal and biomass FT diesel pathways may well be commercially viable within the timeframe of the study (by 2030). Both pathways are evaluated in the JEC study, which looks at fuels and powertrains for year 2010+.

Some additional points to note are,

- The GREET 1.7 manual makes it clear that it only contains placeholder parameters for BTL and we do not know how TIAX dealt with this issue. Therefore results based on GREET will have to be treated with caution.

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[16] Based on TIAX WTT results of 22,184 g GHG/mmBtu for CNG.

[17] Based on TIAX results of 22,969 g GHG/mmBtu for FTD30 and 18,205 g GHG/mmBtu for diesel.

- Biodiesels BD20 have been included in this section although they are not normally considered to be synthetic fuels.

Biodiesels
Biodiesels from palm oil, Midwestern soybean and Californian mustard are listed as pathways evaluated in Table 7-9 in the section on synthetic fuels. However there is no further information on these pathways. In any case, GREET 1.7 manual only lists one biodiesel option, from soybean.

Biodiesels finally receive consideration in their own right in Section 7.5. Yet here again the advertised pathways in Table 7-17 which are described in additional detail in Tables 7-14 to 7-16 do not match the graphed pathways in Figures 7-16 to 7-18. In particular only biodiesel from soybean is shown. The graphs show an additional fuel E-diesel which is not characterised.

Ethanol Pathways
Section 3.8 describes various ethanol pathways, but Table 3-24 which is supposed to provide the assumptions for ethanol from corn, sugarcane and biomass contains only assumptions for corn and a very few assumptions for cellulose. Transport distance assumptions are discussed for ethanol from corn from Nebraska and from sugarcane from Brazil. Table 7-13 contains a list of pathways for E85 fuels, which appears to match the associated Figures 7-10 to 7-15 even though some of the pathway descriptions are different in the table and the figures.

Unconventional crudes
Unconventional crudes do not seem to have been properly represented in the TIAX calculations. We pointed out earlier that TIAX may be confusing tar sands (bitumen) with heavy conventional crudes.

Emissions from extra heavy/oil sands crude depend on the production method. In-situ methods (e.g. steam floods) have a substantially different profile from that of mined tar sands. In Figure 7-2, WtT emissions for RFG from Canadian tar sands are almost twice as much as from RFG from conventional crude. Presumably this is because the default GREET values were used, and GREET emissions are on the high end of estimates[18]. These pathways should be re-analysed.

Raw feedstock and finished fuels from integrated extraction and conversion of oil shales may be imported into California in the LCFS timeframe. Several companies are actively researching and developing oil shale production technologies ranging from mining to in-situ methods, but these technologies are currently still maturing. We do not expect TIAX to include fuels produced from oil shales in the current analysis.

Electricity pathways
No significant comments on the WtT aspects of electricity pathways in California. The marginal analysis is detailed and plausible.

Hydrogen pathways
A wide range of options is considered, with a correspondingly wide spread in WtT emissions. There is one missing pathway, which is a central H2 production facility integrated with the LNG terminal which brings in remote NG. Also, Figures 7-22 to 7-24 contain one extra

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[18] See e.g. compilation by Bandivadekar (2006) and estimates by the Pembina Institute (http://www.pembina.org)

pathway not listed in Tables 7-23 and 7-24, *viz.* H2 from coal with sequestration. There is no discussion of the assumptions behind this pathway.

4.4.2 Excluded Pathways

Cellulostic Ethanol via Enzymatic Hydrolysis

Cellulosic ethanol via enzymatic hydrolysis, e.g. the logen process, is a pathway with significant GHG mitigation potential, which will become commercial within the time frame of the study. This pathway is also evaluated in the JEC study (time frame 2010 and beyond) and the German government sponsored Meo Study of different ethanols. TIAX dismiss this technology in [WTT Section 3.81.1]: "Technologies employing enzymes to break down the cellulose into single sugar molecules rather than acid solutions are the focus of research and are considered emerging technologies at this time."

The enzymatic hydrolysis pathway for cellulosic ethanol should be included.

Renewable diesel via hydrotreating vegetable oils

Renewable diesel obtained through hydrotreating vegetable oil is available commercially as a diesel substitute, e.g. Neste Oil's NeXBTL product. From the perspectives of either GHG emissions or fuel quality, hydrotreated veg oil is a very viable alternative to fatty acid methyl ester biodiesel. This pathway should be included.

The Lurgi process (MtSynfuels) for renewable hydrocarbons

This is another pathway to renewable gasoline and diesel range hydrocarbon fuels starting from methanol. The methanol is converted to olefins, followed by their oligomerisation and separation in gasoline and distillate streams. The distillate is hydrogenated to obtain diesel. The methanol can be synthesised from syngas produced from natural gas or other feedstock through gasification. Lurgi have a pilot plant currently in operation.

Hydrogen from Natural Gas in an integrated LNG/Central H2 processing facility

Process and heat integration efficiencies can be realised if the central H2 production facility is integrated with the LNG terminal through which the remote LNG arrives. Since an LNG terminal may be built in California in the future, this should be included as a pathway to consider.

Pathways incorporating Carbon Capture and Storage

Pathways incorporating carbon capture and storage have not been considered although this could reduce the carbon intensity of pathways amenable to CCS. The Fischer Tropsch diesel pathways are obvious candidates. For example, the Concawe study has included a GTL pathway with CCS which approximately halves the WTT GHG emissions. CCS could similarly reduce emissions from pathways involving unconventional crudes to acceptable levels. Although a coal-to-H2 pathway with CCS appears in Figures 7-22 to 7-24, and a CTL with CCS pathway appears in the pathways ranking in Section 8, there is no other mention of CCS in the WtT report.

4.4.3 The Ranked List of Pathways

Section 8 contains a ranked list of pathways, with some appearing for the first time, e.g. CTL with CCS which gets the highest climate-friendly rating (on a WtT basis) . The basis for this ranking is not discussed, nor is there any discussion of the uncertainties in the results for any of the ranked (or unranked) pathways. There is also no sensitivity analysis. In light of all these findings, we are uncertain as to the value of the ranking .

The graph below compares selected TIAX WtT data with results from the JEC study and the GM-Argonne study. The purpose of this graph is **not** to compare values (which would be misleading in light of the the cautions in Section 2) but instead to point out the wide range in WtT emissions possible for a single fuel product depending on the specific assumptions about the pathway including the feedstock and manufacturing methods and the treatement of coproducts.

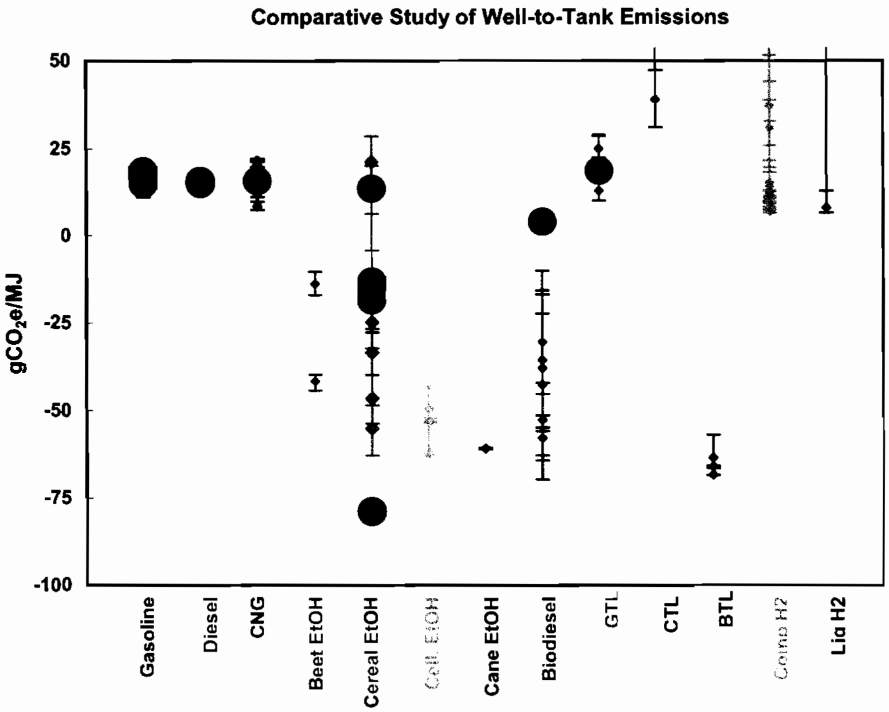

Figure 1 : Well-to-Tank emissions from JEC and GM-Argonne studies plotted alongside selected TIAX results (taken from the WtT spreadsheet). The multicoloured points with error ranges are the JEC values, the filled red circles are GM-Argonne results (for clarity we have not shown their error range) and the filled wine-coloured circles are TIAX results. The cautions in Section 2 regarding inappropriate comparisons of WtW analyses apply here. Note that the most of theTIAX fuels are blended fuels (E10, E85, FT30, BD20, etc.) whereas the JEC values are for neat fuels and fuel components. The highest values of WtT emissions for hydrogen pathways lie outside the range of emissions shown in the figure.

Review of the Tank-to-Wheel Report

4.5 General comments

The TtW report also appears to have similar problems as already noted in the WtT report, and we have compiled a list of some of these problems in this section. The numbers in parentheses refer to the numbered specific comments in Section 5.2 below.

- The report is very general, lacks specifics on how the results are derived. The report contains a large collection of tables and figures that were obtained from outside sources (EMFAC, CCAR, EPA, ... etc.) without descriptions about the bases of how these results were calculated. (1,2,7,8)
- The Abstract does not summarize the content of the report. There are some inconsistencies between the statements in the Abstract and in the main body of the report (4)
- There are some technical inaccuracies in the report (3,10,11,12)
- There is no discussion regarding some of the alternate fuels, e.g. methanol, DME and FT blends, but pollutant adjustment factors are shown for these fuels. (13)
- Section 7, titled Vehicle Cycle Conclusions, contains no conclusions but only limitations.
- The discussion on GHG emissions, including Section 5 appears incomplete (14,15, 16) or unclear. Although this volume of the report is about TtW analysis only data and inputs are presented, there is no attempt to pull these together into conclusions about the TtW emissions.

4.6 Specific Comments

1. The report states that the on-road vehicle fuel consumption and emissions were estimated by the EMFAC and/or EPA certification data, but no details are given.
2. Page 3-20, Section 3.4, the report states that off-road inventory, activity and fuel consumption and emissions were obtained from ARB, but no details are given.
3. In the 3rd paragraph of the Abstract: " These fuel options are of interest because they potentially result in relatively low refuelling emissions". Technically, refuelling emissions are emissions while a vehicle is being filled up with fuel (at a gas station). There is no discussion about refuelling emission in this report.
4. The Abstract states that "Fuels with clearly lower fuel cycle emissions such as compressed natural gas (CNG) and hydrogen were not analyzed in this study". CNG and hydrogen vehicles were analyzed in this report. The Abstract also stated that "Gasoline was also not analyzed as a results of a 1996 fuel-cycle study indicated NMOG emissions to be about 0.03 g/mi". Gasoline is analyzed in this report: it is the baseline.
5. Section 2.2.2, page 2-3, addresses the introduction rates of new technology, Figure 2-2 shows the distribution of new vehicle technology introduced at a fixed market share starting in 2010. However, the report does not give any estimate of the market shares of the new technology.
6. Only a small portion of off-road equipment is addressed in this report. Section 2.3.1, page 2-6, 3rd paragraph, "sixty-five of the 253 equipment types were identified in the

vehicle category used for passenger or goods distribution". As a result, according to Table A-1, appendix A, about 4.5 million gasoline-powered lawn mowers were excluded in this report. The exhaust emissions of these lawn mowers would have significant impacts on criteria and GHG emissions.

7. Table 3-1, page 3-3, shows the baseline on-road fuel consumption for all vehicle classes from 2005 to 2030. The 2005 data were based on the EMFAC model, but there are no details on how future fuel consumptions were estimated. It is not clear why motor homes (MH) have lower fuel consumption (9.2 Mj/mi) than smaller vehicles (MDV, 12.68 Mj/mi).
8. Figure 2-3, page 3-7, shows the fuel economy comparisons for various new technologies. There are no details on how these fuel economy data are calculated. There are two bars for the gasoline PHEV but no explanation about what they are.
9. Figure 3-4, page 3-16, it is not clear why the GM EV-1 data were plotted differently (as a range?) from other vehicles.
10. Page 4-14, 1st paragraph, the statement "The RVP increase arising from the increased RVP of ethanol causes increased evaporative (traditionally measured evaporative HC) emissions for E10 fuel compared to RFG5.7" is not accurate. The additional ethanol in E10 would not result in higher RVP than the E5.7 fuel. Since evaporative emission is a function of the RVP only, E10 and E5.7 with the same RVP should have the same level of evaporative emissions.
11. Page 4-14, 1st paragraph, the statement "E85 formulations are designed to comply with CaRFG3 regulation when used in an FFV that was specifically designed to meet emissions requirement for gasoline fuels containing any concentration of ethanol from E0 to E10" is not accurate. E85 is an alternative fuel, not CaRFG3. FFVs are specifically designed to meet emissions requirement for gasoline fuels containing any concentration of ethanol from E0 to E85.
12. On page 4-14, 4th paragraph on Biodiesel, shouldn't a "compliant California diesel fuel" contain 10% aromatics and 15 ppm sulfur (not 20% and 8 ppm)?
13. Most of the pollutant adjustment factors for alternate fuels (Table 4-10) are either 1 (same as baseline) or 0 (no emission). This seems overly simplistic. For example, NOx emission from E10 would be higher than RFG (E5.7); E85 vehicles may have different emissions than gasoline vehicles.
14. The formula for net CO_2 emissions in Table 5-1 has omitted N_2O emissions, have these been included in Figure 5-1 which presents carbon content for a variety of fuels? For clarity, there should also be another figure which nets out the renewable carbon in these fuels.
15. It is not clear exactly how Figure 3-5 on PHEVs which operate in blended mode using gasoline and electricity could be, or is, used in the WtW analysis.
16. Section 3.2.2 & 3.2.3 mention advances in gasoline ICEs which could improve fuel economy including (direct injection which was analysed in detail in the JEC study) but only hybridisation appears to be included in further analysis.

5. Review of the Well-to-Wheel Report

The WtW report is advertised as presenting results for the multiple years 2012, 2017, 2022, and 2030. In fact we found WtW emissions results for the combined fuel/vehicle system only for the 2012 new vehicle stock although the spreadsheets do contain more information. We did not analyse this volume or review the quantitative results in detail due to lack of time.

In Table 3-1 on the energy and GHG impacts of gasoline vehicles,

- an energy impact of 2 to 20% for tar sands is said to translate into a GHG impact of 15 to 35% but the basis for this claim is not explained. Figures 3-1 and 3-2 are consistent with the lower limits of these ranges.
- Results do not consider advances in internal combustion engine technology beyond hybridisation

Figures 3-7 to 3-8 present results for several Ethanol pathways which were mentioned in the WtT report but not developed further.

- CA Marginal RFG FFV is more energy and emissions intensive than the equivalent ICEV pathway in spite of the FFV fuel economy being in the higher end of the ICEV range (Figure 2-2) ? Is this because the FFV been optimised for E85 use ?

Figures 3-19 to 3-21 depict results for Electricity pathways including both EVs and PHEVs. The fuel consumption gains following hybridisation would depend on the split between gasoline and all-electric modes which is influenced by the real-life drivecycle. We would like to understand to what extent has this been tested and validated.

5.1 Two Further Ranked List of Pathways

Section 5.1 presents another two ranked lists of selected pathways, one for light duty applications and the other for heavy duty. . There is no discussion of how all the other pathways considered in the reports compare with these selections. Our comments on the ranking in the WtT report could also apply to these lists: ranking without defined criteria, lack of discussion of uncertainties in the results and no sensitivity analysis

6. Concluding Remarks

In sum, while it is apparent that TIAX has invested significant effort in the generation of these reports, much work remains to be done. We have found some shortcomings and flaws in the TIAX analysis which should be addressed before the analysis can be used either for scenario development or for developing a low carbon regulatory standard. We look forward to working with TIAX in improving the calculations and in bringing the analysis to a satisfactory conclusion.