UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TESLA INC.,
Petitioner

v.

CHARGE FUSION TECHNOLOGIES LLC,
Patent Owner

Case No. IPR2025-00153
Patent No. 11,531,987

DECLARATION OF JUNE ANN MUNFORD

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I earned a Master of Library and Information Science (MLIS) from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector, including Assistant Librarian, Youth Services Librarian, and Library Director. I have attached my curriculum vitae as Appendix CV.

3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased, and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs, and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog search performance, and creating lending agreements between libraries during my time as a Library Director.

4. I have written this declaration at the request of Petitioner, Tesla Inc., to provide my expert opinion regarding the public availability of Exhibit 1007, "The V2G Concept, A New Model for Power" by Steven E. Letendre, Ph.D., and Willett Kempton, Ph.D. as published in *Public Utilities Fortnightly*, Vol. 140, No. 4, dated February 15, 2002. Specifically, I have been asked to determine whether Exhibit 1007 was publicly available more than one year prior to the priority date of the patent at issue, which I have been informed is July 13, 2009. My Declaration sets forth my opinions and provides the basis for my opinions regarding the authenticity and public availability of Exhibit 1007.

5. Exhibit 1007 is a true and correct copy of "The V2G Concept, A New Model for Power," published in *Public Utilities Fortnightly*, Vol. 140, No. 4, as held by the Western Michigan University library. These scans were secured from the library's collection.

6. I am being compensated for my services in this matter at the rate of $200.00 per hour plus reasonable expenses. My statements are objective, and my compensation does not depend on the outcome of this matter. All of the

materials that I considered and relied upon in forming my opinions are discussed below.

7. Attached hereto as Appendix LETENDRE01 is a true and correct copy of the MARC record for *Public Utilities Fortnightly* as held by the Western Michigan University library.

8. I am fully familiar with the catalog record creation process in the library sector. In preparing material for public availability, a library catalog record describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as "MARC") code and contain information such as a physical description of the material, metadata from the material's publisher, and date of library acquisition. In particular, the 008 field of the MARC record is reserved for denoting the date of creation of the library record itself.

9. Typically, in creating a MARC record, a librarian gathers metadata such as book title, publisher, and subject headings, among others, and assigns each value to a relevant numerical field. For example, a book's physical description is tracked in field 300, while title/attribution is tracked in field 245. The 008 field of the MARC record is reserved for denoting the creation of the library record itself.

10. MARC records are used to catalog many different types of media, including journals, magazines, and other periodicals. These types of serial publications have the same collective title but are intended to be continued indefinitely with enumeration, such as a volume or issue number. Typically, the first issue of the serial publication is cataloged by creating a corresponding MARC record, but the date is left open-ended with the use of a punctuation mark such as a dash, for example, in field 362. In my professional experience, it is highly unusual for a library to stop collecting and shelving a serial publication prior to the end of its publication run. If a subscription to a serial publication ends its run or is canceled before the end of its run, the library will denote that it has stopped receiving new volumes by filling in the end date in the MARC record.

11. The MARC record contained within Appendix LETENDRE01 accurately describes the title, publisher, and ISSN number of *Public Utilities Fortnightly,* as shown on page 6 of Exhibit 1007. Field 362 of the MARC record indicates that the Western Michigan University library first cataloged the *Public Utilities Fortnightly*, Vol. 132, no. 16 (Sept. 1, 1994) and continued receiving subsequent issues in perpetuity as indicated by the dash in the MARC record:

```
362    0#$aVol. 132, no. 16 (Sept. 1, 1994)-
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Appendix LETENDRE01 at 1.

12. The 'Holdings' field of this record visible on page 2 indicates this collection includes the February 15, 2002 edition of *Public Utilities Fortnightly* containing Exhibit 1007:

Waldo Library **General Stacks, Does Not Circulate** **HD2763.A2 P8x** LOCATE
Hide Details

Holdings: v.132,no.16-v.149 (Sept.1,1994-2011)
Incomplete: v.133.

Appendix LETENDRE01 at 2 (emphasis added).

13. My determination that the MARC record contained within Appendix LETENDRE01 accurately describes *Public Utilities Fortnightly* is based upon the accuracy of several fields within this MARC record. The 022 field, describing the journal's ISSN, matches the ISSN of *Public Utilities Fortnightly* as represented in Exhibit 1007. The 245 field, describing the title of the journal, matches the title as represented in Exhibit 1007. The 260 field describing the publisher of the work is properly attributed to Public Utilities Reports, Inc., as found in Exhibit 1007.

14. Page 4 of Exhibit 1007 confirms that Western Michigan University had an active subscription to *Public Utilities Fortnightly* via the existence of a label on the cover of the journal. Based on my experience, the date found on this subscription label indicates that at the time of receipt of this issue, i.e., February 2002, the library's subscription was active until January 2003, at which point it would need to be renewed:

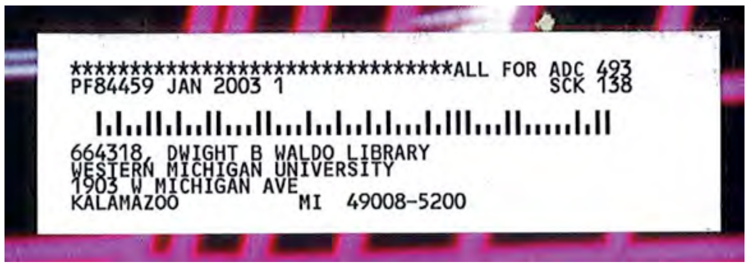


Exhibit 1007 at 4.

15. Exhibit 1007 also contains a stamp visible on page 5 indicating that an employee of Western Michigan University Library stamped the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue on February 13, 2002:

Exhibit 1007 at 5.

16. This existence of this stamp indicates that the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue was printed and shipped to subscribers on or before

February 13, 2002, so that it could be publicly available on or before the issue date of February 15, 2002.

17. Page 6 of Exhibit 1007 includes information regarding the copyright and publisher. Specifically, the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue is marked with "© Copyright 2002 by Public Utilities Reports Inc" and has an ISSN of 1074-6099:

> © Copyright 2002 by Public Utilities Reports Inc. All Rights Reserved. Publ
> Utilities Fortnightly (ISSN 1074-6099) is published semi-monthly, excep
> monthly in August and December, by Public Utilities Reports Inc. Executiv
> and editorial offices at 8229 Boone Boulevard, Suite 401, Vienna, VA 2218
> Tel: 703-847-7720, Fax: 703-847-0683. Email: pur@pur.com
> **EXECUTIVE MANAGEMENT:** Randall F. Spencer, Chairman, Presider
> and CEO; Susan M. Johnson, Executive Vice President and Secretary
> Jennings B. Yowell, Vice President and Treasurer; Robert V. Burns, Assistar
> Vice President and Chief Financial Officer.

Exhibit 1007 at 6.

18. Exhibit 1007 also includes a publication data page on page 6 that indicates the work's broader availability from other sources. A passage from this page reads: "The Public Utilities Fortnightly Database is accessible through LEXIS/NEXIS and WESTLAW":

> Please allow 4 to 6 weeks for changes.
> The Public Utilities Fortnightly Database is accessible throug
> LEXIS®/NEXIS® and WESTLAW®

Exhibit 1007 at 6.

19. Attached hereto as Appendix LETENDRE02 is a true and correct copy of the MARC record for *Public Utilities Fortnightly* as held by the Penn State University library.

20. The MARC record contained within Appendix LETENDRE02 accurately describes the title, author, publisher, and ISSN number of *Public Utilities Fortnightly* as shown on page 6 of Exhibit 1007. Field 362 of the MARC record indicates that the Penn State University library first cataloged the *Public Utilities Fortnightly*, Vol. 132, no. 16 (Sept. 1, 1994) and continued receiving subsequent issues in perpetuity as indicated by the dash in the MARC record:

362	0	a| Vol. 132, no. 16 (Sept. 1, 1994)-

Appendix LETENDRE02 at 1.

21. The availability field of the Penn State MARC record serves as an inventory of the library's holdings. The 'Availability' field of this record, visible on page 3, shows a "2002" volume, confirming that this collection includes the February 15, 2002 edition of *Public Utilities Fortnightly* containing Exhibit 1007.

Availability

I Want It

Penn State Law (University Park) (13 items)

Call number	Material	Location
Periodical v.146 2008	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.145 2007	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.144 2006	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.143 2005	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.142 2004	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.141 2003	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.140 2002	Bound Journal	Being transferred between libraries
Periodical v.139 2001	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.138 2000	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.135 1997	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.134 1996	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.133 1995	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals
Periodical v.132 Sep-Dec 1994	Bound Journal	Penn State Law (UP) - 3rd Floor - Periodicals

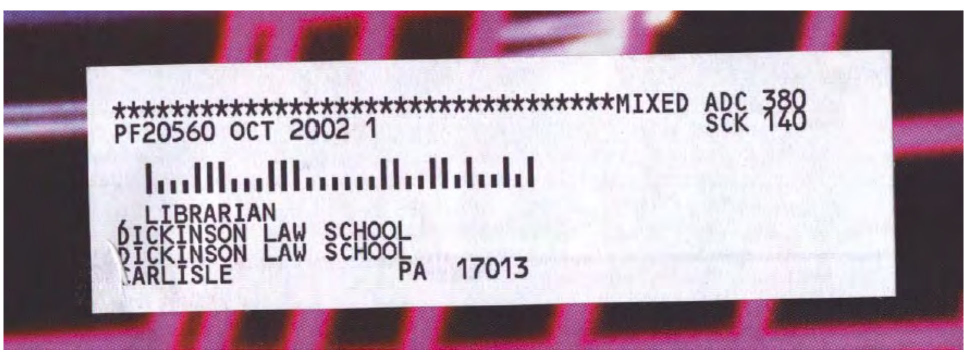
Appendix LETENDRE02 at 3 (emphasis added).

22. My determination that the MARC record contained within Appendix LETENDRE02 accurately describes *Public Utilities Fortnightly* is based upon the accuracy of several fields within this MARC record. The 022 field, describing the journal's ISSN, matches the ISSN of *Public Utilities Fortnightly* as represented in Exhibit 1007. The 245 field, describing the title of the journal, matches the title as represented in Exhibit 1007. The 260 field describing the publisher of the work is properly attributed to Public Utilities Reports, Inc., as found in Exhibit 1007.

23. Attached hereto as Appendix LETENDRE03 is a true and correct copy of "The V2G Concept: A New Model for Power" as published in *Public*

Utilities Fortnightly, Vol. 140, No. 4, as held by the Penn State University library. I secured these scans myself from the library's collection. In comparing Exhibit 1007 to Appendix LETENDRE03, it is my determination that Exhibit 1007 is a true and correct copy of "The V2G Concept, A New Model for Power," published in *Public Utilities Fortnightly*, Vol. 140, No. 4, dated February 15, 2002.

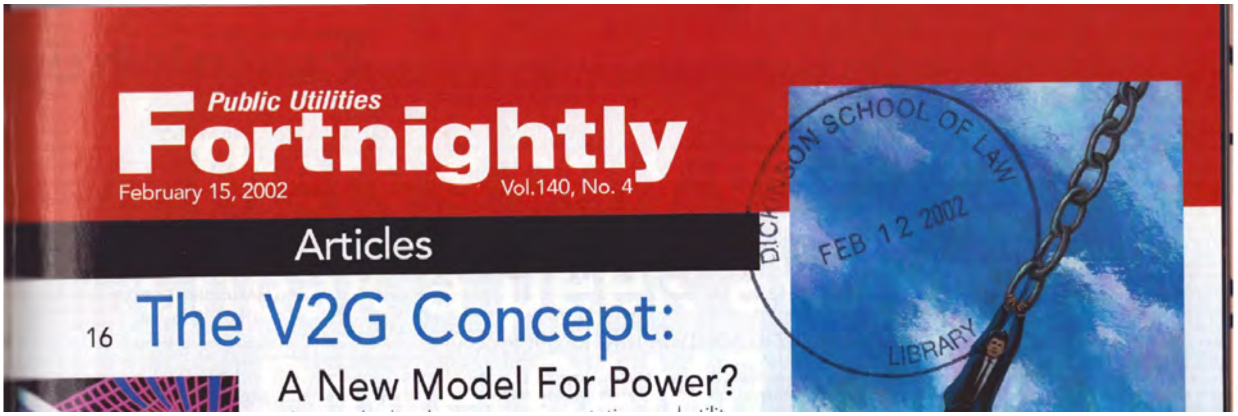
24. Page 5 of Appendix LETENDRE03 confirms that Penn State University's Dickinson School of Law had an active subscription to *Public Utilities Fortnightly* via the existence of a label on the cover of the journal. Based on my experience, the date found on this subscription label indicates that at the time of receipt of this issue, i.e., February 2002, the library's subscription was active until October 2002, at which point it would need to be renewed:



Appendix LENTENDRE03 at 5.

25. Appendix LENTENDRE03 also contains a stamp visible on page 6 indicating that an employee of Penn State's Dickinson School of Law

Library stamped the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue on February 12, 2002:



Appendix LENTENDRE03 at 6.

26. This existence of this stamp further confirms that the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue was printed and shipped to subscribers on or before February 12, 2002, so that it could be publicly available on or before the issue date of February 15, 2002.

27. Due to the fact that Exhibit 1007 was received by multiple libraries before February 15, 2002, it is my opinion that the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue, and the article "The V2G Concept: A New Model for Power" contained in Exhibit 1007, was made available to the public at least by February 15, 2002, which is several years prior to the July 13, 2009 priority date of the patent at issue in this matter.

28. I am familiar with the Internet Archive, a digital library formally certified by the State of California as a public library. Among other services that the Internet Archive makes available to the general public is the Wayback Machine, an online archive. The Internet Archive's Wayback Machine service archives webpages as of a certain capture date to track changes in the web over time. The Internet Archive has been in operation as a nonprofit library since 1996 and has hosted the Wayback Machine service since its inception in 2001. During my time as a librarian, I frequently used the Internet Archive's Wayback Machine for research and instruction purposes. This includes teaching instructional classes on using the Wayback Machine to library patrons and using the Wayback Machine to research reference inquiries that require hard-to-find online resources. I consider the Internet Archive's recordkeeping to be as rigorous and detailed as other formal library recordkeeping practices such as MARC records, OCLC records, and Dublin Core.

29. Attached hereto as Appendix IA01 is a screen capture of the Internet Archive Wayback Machine entry for http://www.libraries.psu.edu/crsweb/instruction/ip/CAT_guide.htm. I secured these screen captures myself from

https://web.archive.org/web/20021101000000*/http://www.libraries.psu.edu/crsweb/instruction/ip/CAT_guide.htm.

30. Appendix IA01 is a webpage entitled *Quick Guide to Searching in the Enhanced CAT* as published on the Penn State University library website, captured by the Internet Archive on June 3, 2002. This page describes user options when interacting with the Penn State University library catalog as such: 'Be sure to choose the search type you want before you begin your search. Choose BROWSE for an exact title, journal title, series, or LCS heading. Choose KEYWORD for searching topics. Choose QUICK SEARCH for simple keyword searches on unique words or phrases. Choose CALL NUMBER for browsing by call number within a library or collection.' This page also indicates that Penn State University's library records are designed to correspond with the library's holdings: "If you see a shelf location in the enhanced CAT, the item is available and should be on the shelf. In other words, assume an item is available unless the system tells you it is checked out, in process, etc."

31. Appendix IA01 indicates the Penn State University library created a detailed inventory of the library's holdings and presented users with an interactive library catalog to search this inventory as of June 3, 2002 and likely before

this date. I note that the Dickenson School of Law Library is one of several library locations within the Penn State University Libraries umbrella. Therefore, the Dickenson School of Law Library's holdings would have been accessible through Penn State University's interactive library catalog. As such, it is my determination that the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue and, therefore, Exhibit 1007 was sufficiently indexed at the time of its acquisition by the Penn State University Library by February 15, 2002. This indexing via Penn State University's Library catalog records allows any library catalog user to locate articles in issues of *Public Utilities Fortnightly* obtained by the library. Therefore, members of the public would have been able to locate Exhibit 1007 via common search engine practices and access this article within the Penn State University library's collection. Thus, any members of the interested public exercising reasonable diligence would have been able to locate the *Public Utilities Fortnightly*, Vol. 140, No. 4 issue and, therefore, Exhibit 1007 in the Penn State University Library on or around February 15, 2002, and certainly years prior to the July 13, 2009 priority date of the patent at issue.

32. Additionally, several references had cited Exhibit 1007 prior to the July 13, 2009 priority date of the patent at issue, further confirming that Exhibit 1007 was available to members of the interested public more than one year prior

to July 13, 2009. For example, Appendix FERNANDEZ01 is U.S. Patent No. 7,374,003 to Fernandez, titled "Telematic Method and Apparatus with Integrated Power Source," which was filed on November 28, 2005, and issued on May 20, 2008. Appendix FERNANDEZ01 at 1. Appendix FERNANDEZ01 cites Exhibit 1007 on page 2 of the patent:

> Steven E. Letendre & Willett Kempton, "The V2G Concept: A New Model for Power?", Public Utilities Fortnightly, Feb. 15, 2002.

Appendix FERNANDEZ01 at 2.

33. A copy of Appendix FERNANDEZ01 can be downloaded from the following website: https://patents.google.com/patent/US7374003B1/en?oq=7%2c374%2c003+

34. Appendix FERDOWSI01 is a conference paper called "Plugin Hybrid Vehicles – A Vision for the Future" by Mehdi Ferdowsi. FERDOWSI01 was presented at the 2007 IEEE Vehicle Power and Propulsion Conference between the dates of September 9 and September 12 and was added to IEEE Explore on June 17, 2008:

Published in: 2007 IEEE Vehicle Power and Propulsion Conference

Date of Conference: 09-12 September 2007 **DOI:** 10.1109/VPPC.2007.4544169

Date Added to IEEE *Xplore*: 17 June 2008 **Publisher:** IEEE

Appendix FERDOWSI02 at 1.

35. Exhibit 1007 is cited as reference number 6 of FERDOWSI01:

[6] Letendre, S., and Kempton, W., "The V2G Concept: A New Model for Power?," Public Utilities Fortnightly 140(4): 2002, pp. 16-26.

FERDOWSI01 at 461.

36. A copy of Appendix FERDOWSI01 can be downloaded from the following website: https://ieeexplore.ieee.org/document/4544169.

37. Appendix LETENDRE05 is a copy of the Proceedings at the International Workshop on Hybrid and Solar Vehicles that took place on November 5-6, 2006. The Proceedings include a paper titled "Ushering in an Era of Solar-Powered Mobility" by Steven E. Letendre, PhD. Appendix LETENDRE05. Exhibit 1007 is cited on page 9 of the paper:

Letendre, S and W. Kempton. (2002). V2G: a new model for power?. *Public Utilities Fortnightly*, **140**, 16-26.

Appendix LETENDRE03 at 9.

38. A copy of Appendix LETENDRE05 can be downloaded from the following website: https://scholar.google.com/scholar?cluster=2181104445580902 74&hl=en&as_sdt=5,30&sciodt=0,30&as_yhi=2008.

39. Appendix WILLIAMS01 is a PhD dissertation by Brett David Williams submitted to the office of Graduate Studies at the University of California Davis in 2007. Appendix WILLIAMS01 at i. Exhibit 1007 is listed as reference number 12 on page 267 of the dissertation:

[12] S. Letendre and W. Kempton, "The V2G Concept: A New Model For Power?" *Public Utilities Fortnightly*, pp. 26, 2002.

Appendix WILLIAMS01 at 267.

40. A copy of Appendix WILLIAMS01 can be downloaded from the following website: https://escholarship.org/uc/item/16k010cq.

41. Appendix TERLOUW01 is a thesis submitted for a Master's degree by Jeroen Terlouw to the University of Twente on August 28, 2007. Exhibit 1007 is cited on page 65 of the thesis:

Letendre, Steven E., Willet Kempton (2002) The V2G-concept: a new model for power? Connecting utility infrastructure and automobiles. Public Utilities Fortnightly, February 15.

Appendix TERLOUW01 at 65.

42. A copy of Appendix TERLOUW01 can be downloaded from the following website: https://essay.utwente.nl/768/.

43. Appendix ROMM01 is a journal article titled "The car and fuel of the future" by Joseph Romm in *Energy Policy* in Volume 37, Issue 17 dated November of 2006:

ScienceDirect

Energy Policy

Volume 34, Issue 17, November 2006, Pages 2609-2614

Appendix ROMM02 at 1.

44. ROMM01 was also available online on August 8, 2005.

The car and fuel of the future

Joseph Romm [1]

Center for Energy and Climate Solutions, 2900 South Quincy Street, Suite 410, Arlington, VA 22206, USA

Available online 8 August 2005.

ROMM02 at 1.

45. Exhibit 1007 is cited on page 2614 of ROMM01:

Letendre, S., Kempton, W., 2002. The V2G [Vehicle to Grid] concept: a new model for power? Public Utilities Fortnightly, 16–26 February 15.

ROMM01 at 2614.

46. A copy of Appendix ROMM01 can be downloaded from the following website: https://www.sciencedirect.com/science/article/abs/pii/S0301421505001734#preview-section-references.

47. The fact that multiple documents cited Exhibit 1007 prior to the priority date of the patent at issue further confirms that members of the interested public exercising reasonable diligence were able to locate Exhibit 1007.

48. I declare under penalty of perjury that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 10/14/2024

June Ann Munford

Appendix CV

June A. Munford
Curriculum Vitae

Education

University of Wisconsin-Milwaukee - MS, Library & Information Science, 2009
Milwaukee, WI

- Coursework included cataloging, metadata, data analysis, library systems, management strategies and collection development.
- Specialized in library advocacy, cataloging and public administration.

Grand Valley State University - BA, English Language & Literature, 2008
Allendale, MI

- Coursework included linguistics, documentation and literary analysis.
- Minor in political science with a focus in local-level economics and government.

Professional Experience

Researcher / Expert Witness, October 2017 – present
Freelance ● Pittsburgh, Pennsylvania & Grand Rapids, Michigan

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.

- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.

- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

Library Director, February 2013 - March 2015
Dowagiac District Library ● Dowagiac, Michigan

- Executive administrator of the Dowagiac District Library. Located in

Southwest Michigan, this library has a service area of 13,000, an annual operating budget of over $400,000 and total assets of approximately $1,300,000.

● Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.

● Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.

● Led the organization and digitization of the library's archival records.

● Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.

● Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013
Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

● Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.

● Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.

● Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013
Library Assistant, Hart Area Public Library
Hart, MI

● Responsible for verifying imported MARC records and original MARC cataloging for the local-level collection as well as the Michigan Electronic Library.

● Handled OCLC Worldcat interlibrary loan requests & fulfillment via ongoing communication with lending libraries.

Professional Involvement

Alaska Library Association - Anchorage Chapter
- Treasurer, 2012

Library Of Michigan
- Level VII Certification, 2008
- Level II Certification, 2013

Michigan Library Association Annual Conference 2014
- New Directors Conference Panel Member

Southwest Michigan Library Cooperative
- Represented the Dowagiac District Library, 2013-2015

Professional Development

Library Of Michigan Beginning Workshop, May 2008
Petoskey, MI
- Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011
Nashville, TN
- Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012
Fairbanks, AK
- Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

Depositions

2019 ● Fish & Richardson

Apple v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282 and 39521-00421IP2)

2019 ● Erise IP

Implicit, LLC v. Netscout Systems, Inc (Civil Action No. 2:18-cv-53-JRG)

2019 ● Perkins-Coie

Adobe Inc. v. RAH Color Technologies LLC (Cases IPR2019-00627, IPR2019-00628, IPR2019-00629 and IPR2019-00646)

2020 ● O'Melveny & Myers

Maxell, Ltd. v. Apple Inc. (Case No. 5:19-cv-00036-RWS)

2021 ● Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (IPR2020-1449)

2022 ● Perkins-Coie

Realtek v. Future Link (IPR2021-01182)

2023 ● Fish & Richardson

Neuroderm Ltd. v. Abbvie, Inc (Case No. PGR2022-00040)

2023 ● Fish & Richardson

Nearmap US Inc. v. Pictometry International Corp. (IPR2022-00735)

2023 ● Fish & Richardson

Samsung Electronics v. MemoryWeb LLC (Case No. 39843-0136PS1)

2023 ● Pillsbury Winthrop Shaw Whitman LLP

Gravel Rating Systems v. Costco Wholesale Corp. (Civil Action No. 4:21-cv-149-ALM)

2024 ● Willkie-Farr

Netflix, Inc. v. VideoLabs. Inc. (IPR2023-00628)

Limited Case and Clientele History

Alston & Bird

- Ericsson

  v. Collision Communications (IPR2022-01233)

- Nokia

  v. Neptune Subsea, Xtera (Case No. 1:17-cv-01876)

- Universal Electronics Inc

  v. Roku Inc (IPR2022-00818)

Arnold & Porter

- Ivantis

  v. Glaukos (Case No. 8:18-cv-00620)

- Samsung

  v. Jawbone (Case No. 2:21-cv-00186)

Benesch Friedlander Coplan & Aronoff

- Voyis
    - v. Cathx (Case No. 5:21-cv-00077-RWS)

Deschert LLP

- Smaxtec Animal Care
    - v. ST Reproductive Technologies, LLC (IPR2024-00885)

Erise I.P.

- Apple
    - v. Ericsson Inc. (IPR2022-00715)
    - v. Future Link Systems (IPRs 6317804, 6622108, 6807505, and 7917680)
    - v. INVT (Case No. 20-1881)
    - v. Navblazer LLC (IPR2020-01253)
    - v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)
    - v. Quest Nettech Corp (Case No. 2:19-cv-00118-JRG)
    - v. Telefonaktiebolaget LM Ericsson (IPR2022-00275)
    - v. Theta IP, LLC (IPR2024-00818)

- Fanduel
    - v. CGT (Case No. 19-1393)

- Garmin
    - v. Phillips North America LLC (Case No. 2:19-cv-6301-AB-KS)

- Netscout

    v. Longhorn HD LLC (Case No. 2:20-cv-00349)

    v. Implicit, LLC (Civil Action No. 2:18-cv-53-JRG)

- Sony Interactive Entertainment LLC

    v. Bot M8 LLC (IPR2020-01288)

    v. Infernal Technology LLC (Case No. 2:19-CV-00248-JRG)

- Unified Patents

    v. GE Video Compression (Civil Action No. 2:19-cv-248)

Fish & Richardson

- Apple

    v. AliveCor (3:21-cv-03958)

    v. LBS Innovations (Case No. 2:19-cv-00119-JRG-RSP)

    v. Koss Corporation (IPR2021-00305)

    v. Masimo (IPR 50095-0012IP1, 50095-0012IP2, 50095-0013IP1, 50095-0013IP2, 50095-0006IP1, 50095-0135IP1)

    v. Neonode (Case No. 21-cv-08872-EMC)

    v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)

- Dell

    v. Neo Wireless (IPR2022-00616)

- Dish Network

    v. Entropic Communications, LLC (Case No. 2:2023-CV-01043)

v. Realtime Adaptive Streaming (Case No. 1:17-CV-02097-RBJ)

v. TQ Delta LLC (Case No. 18-1798)

- Evapco Dry Cooling

  v. SPG Dry Cooling (IPR2021-00688)

- Genetec

  v. Sensormatic Electronics (Case No. 1:20-CV-00760)

- Huawei

  v. Bell Northern Research LLC (IPR2019-01174)

- Kianxis

  v. Blue Yonder (Case No. 3:20-cv-03636)

- LG Electronics

  v. Bell Northern Research LLC (Case No. 3:18-cv-2864-CAB-BLM)

- Metaswitch

  v. Sonus Networks (IPR2018-01719)

- Microsoft

  v. Throughputer Inc (IPR2022-00757)

- Mom Enterprises

  v. Ddrops Company (Case No. 1:22-cv-00332)

- MLC Intellectual Property

v. MicronTech (Case No. 3:14-cv-03657-SI)

- Nearmap Inc

  v. EagleView Technologies (IPR2022-01009)

- Neuroderm Ltd.

  v. Abbvie, Inc (Case No. PGR2022-00040)

- Realtek Semiconductor

  v. Future Link (IPR2021-01182)

- Quectel

  v. Koninklijke Philips (Case No. 1:20-cv-01710)

- Samsung

  v. Aire Technology (IPR2022-00877)

  v. Bell Northern Research (Case No. 2:19-cv-00286-JRG)

  v. Communication Technologies Inc (IPR2022-01221)

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  v. Vantage Micro LLC (IPR2020-01261)

- Xilinx

  v. Sentient Sensors LCC (Case No. 1:22-cv-00173)

Groombridge Wu

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  v. Eagle View Technologies Inc. and Pictometry International Corp. (Case No. 2:21-cv-00283-TS-DAO)

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- Curium

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- Micron Technology Inc.

  v. Besang Inc (IPR2023-00900)

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- Realtek Semiconductor

  v. Future Link (IPR2021-01182)

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  v. VOIP-Pal.com (Case No. 3:20-cv-02397-JD)

- TCL Industries

  v. Koninklijke Philips NV (IPR2021-00495, IPR2021-00496 and IPR2021-00497)

Pillsbury Winthrop Shaw Pittman

- Intel

  v. FG SRC LLC (Case No. 6:20-cv-00315)

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Quinn Emanuel

- ServiceNow, Inc.

  v. InQuisient, Inc. (Case No. 22-900-CJB)

- Wolfspeed

  v. The Trustees of Purdue University (Case No. 1:2021-cv-00840)

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  v. Semiconductor Design Technologies (Case No. 3:23-cv-01001)

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  v. The Foundry, LLC (IPR2024-00669)

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949			a| Periodical v.132 Sep-Dec 1994 w| LCPER c| 1 i| 35189001681220 d| 4/3/1995 l| PERBND-DP m| DSL-UP r| Y s| Y t| BNDSER-DSL

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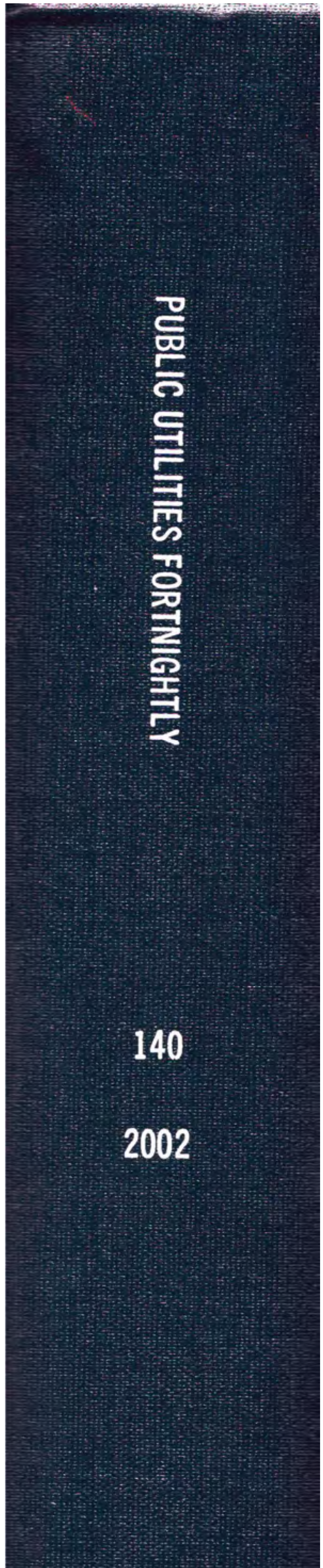
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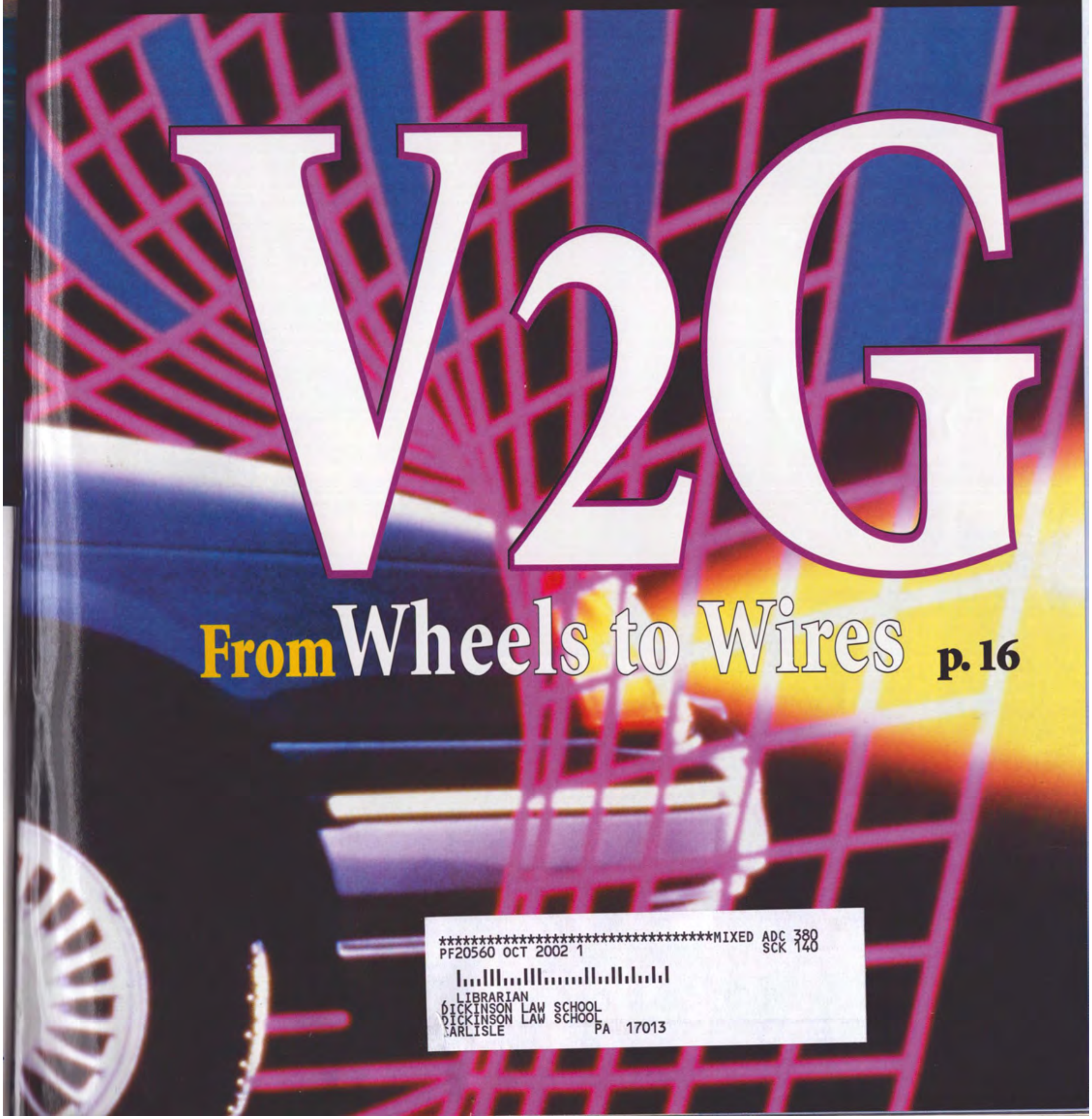
V2G

From Wheels to Wires p. 16



Public Utilities **Fortnightly**
February 15, 2002 Vol.140, No. 4

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2. Power Generation Developers' Commercial Demand
3. Gas Transmission Operators Pricing of Capacity Issues
4. Gas Transmission System Design
5. Regulatory Obligations to Ensure Equality of Services

See p. 32

The V2G Concept: A New Model For Power?

Connecting utility infrastructure and automobiles.

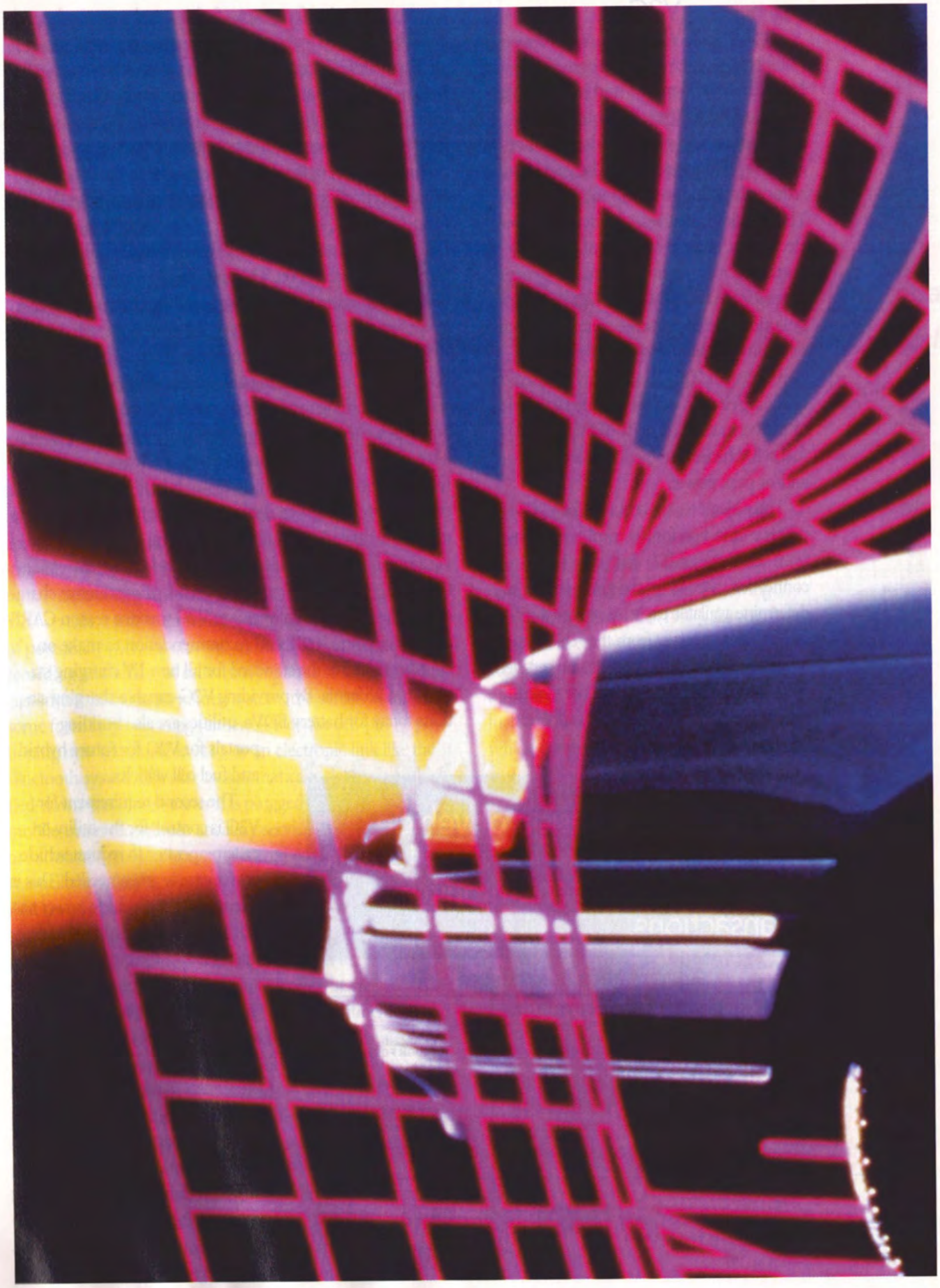
By Steven E. Letendre, Ph.D., and Willett Kempton, Ph.D.

ELECTRIC-DRIVE VEHICLES CAN BE THOUGHT OF as mobile, self-contained, and—in the aggregate—highly reliable power resources. "Electric-drive vehicles" (EDVs) include three types: battery electric vehicles, the increasingly popular hybrids, and fuel-cell vehicles running on gasoline, natural gas, or hydrogen. All these vehicles have within them power electronics which generate clean, 60 Hz AC power, at power levels from 10kW (for the Honda Insight) to 100kW (for GM's EV1). When vehicle power is fed into the electric grid, we refer to it as "Vehicle-to-Grid" power, or V2G.

Electric utility planners and strategists, when they think about electric-drive vehicles at all, have seen battery vehicles as night-charge (valley-filling) load, and perhaps have seen fuel cell vehicles as possible generation resources for some distant future. In contrast, a recent study we conducted for the California Air Resources Board (CARB) and the Los Angeles Department of Water and Power, shows all three types of EDVs (battery, hybrid, and fuel cell) have potential roles to play as utility resources, and that ancillary services are the most lucrative use for vehicle power.

The electric power resource from vehicles is potentially quite large. In California alone, we calculate that CARB's zero emission vehicle mandates will provide 424 MW of power capacity by 2004, and 2.2 GW by 2008 (Kempton et al., 2001: 22). Looking further into the future, the Electric Power Research Institute (EPRI) predicts that power from electric-drive vehicles could reduce the global requirement for central station generation capacity by up to 20 percent by the year 2050 (EPRI 2001).

Our study assesses the technical requirements, electrical capacity, and economic value of V2G. We examined a range of EDVs to provide four types of power: baseload, peak, spinning reserves, and regulation (up and down). V2G for baseload power does not make sense, as the per-kWh cost is too high and drive train designs assume low operating time (average 1 hour/day). However, the economic value of other forms of V2G appears high, more than enough to offset the initially higher costs of electric-drive vehicles. To realize this potential, however, will require some minor design modifications to current vehicles, and some coordination of vehicle and infrastructure planning.



V2G: How it Would Work

California, along with New York, Massachusetts, Vermont, and Maine, have embarked on policies to encourage the development and spread of electric-drive and low pollution vehicles. The goal is to reduce air pollution from mobile sources. These policy initiatives, advances in power electronics, and the opening of electricity markets across the country create opportunities for electric-drive vehicles to reduce air pollution, and at the same time increase the reliability and efficiency of the electric power system. This opportunity is based on using the electric storage of battery vehicles, or the generation capacity of hybrid and fuel cell vehicles, for ancillary services and/or peak power.

Three elements are required for V2G: 1) power connection for electrical energy flow from vehicle to grid, 2) control or logical connection, needed for the grid operator to determine available capacity, request ancillary services or power from the vehicle, and to meter the result, and 3) precision certified metering on board the vehicle. For fueled vehicles (fuel cell and hybrid), a fourth element, a connection for gaseous fuel (natural gas or hydrogen), could be added so that on board fuel is not depleted.

The first V2G requirement is the power connection. Battery vehicles must already be connected to the grid in order to recharge their batteries; to add V2G capability requires little or no modification to the charging station and no modification to the cables or connectors, but on board power electronics must be designed for this purpose. AC Propulsion, Inc., a manufacturer of electric vehicle drive trains, tested the first vehicle power electronics built for this purpose in August 2000. They informally reported that designing in reverse power flow had "zero incremental cost." Propulsion's current V2G power electronics, though, with extensive control and safety to ensure no back feeding of power onto the grid during an outage, added $400 to the initial cost, assuming moderate production runs. Thus, the on board power connections and power control needed for V2G have already been demonstrated, and are now a standard feature of one company's vehicle-drive units. (The same company is currently testing demonstration vehicles that provide regulation up and regulation down in real time, controlled via a signal from the California Independent System Operator.) The ease of adapting on board conductive chargers (versus inductive chargers) to V2G was one reason CARB adopted, in June 2001, staff recommendation to make on board conductive the standard for all new EV charging stations in California. By providing V2G-capable charging stations today for battery EDVs, utilities are also building portals for V2G for future hybrid and fuel cell vehicles.

The second requirement for V2G is control, for the utility or system operator to request vehicle power exactly when needed. This is essential because vehicle power has value greater than the cost to produce it only if the buyer (the system operator) can determine the precise timing of dispatch. The automobile industry is moving towards making real-time communications a standard part of vehicles. This field, called "telematics" has already begun with luxury vehicles; over a period of time it will be available for most new car models. Whether using built-in vehicle telematics, or in the interim using add-on communications, the

Figure 1: Suggested design of vehicle dashboard control, allowing driver to limit loss of range of vehicle and monitor power transactions.

Source: Kempton and Letendre, 1997

IPR2025-00153
Tesla EX1086 Page 52

vehicle could receive a radio signal from the grid operator indicating when power is needed.

The third element of precision, certified, tamper-resistant metering, measures exactly how much power or ancillary services a vehicle did provide, and at which times. Such devices are currently available to manufacture for under $10. The telematics could again be used to transmit meter readings back to the buyer for credit to the vehicle owner's account.

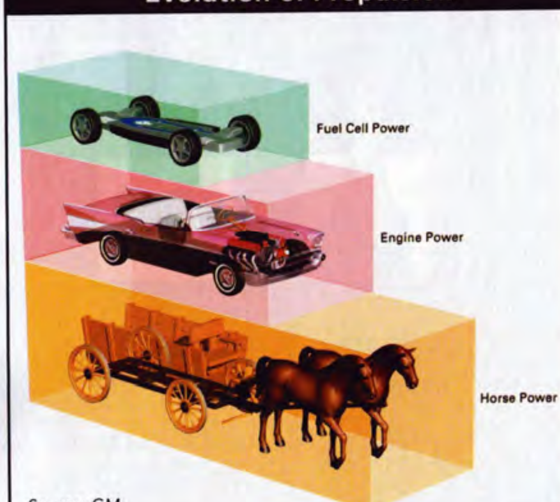
Thinking about the metering of V2G expands our usual concept of a "utility meter." Electronic metering and telematics appear to have efficiency advantages in eliminating the meter reader, transfer of billing data to the central computer, and the monthly meter-read cycle. More unnerving, electronic metering and telematics also eliminates the service address! An onboard meter would transmit its own serial number or account number with its readings, via telematics, and presumably this would be billed in conjunction with a traditional metered account with a service address. A large-scale V2G system would automate accounting and reconciliation of potentially millions of small transactions, similar to the recording and billing of calls from millions of cellular phone customers. In the most refined system, the vehicle could use some form of positioning (either GPS or the cell-phone positioning now required for 911), or an electronic link like the Bluetooth system, in order to automatically determine which tied-down traditional meter it is plugged in to. Thus, the mobile-metered kWhs or ancillary services would be added or subtracted to the amount registered on the fixed-meter to reconcile both billing amounts. On board metering and verification of where the vehicle is plugged in are required for business models that allow a vehicle to sell power while at a public power station or otherwise away from its home garage. However, since the vehicle will often be plugged into the owner's building meter anyway, these are refinements that could be saved until second-generation V2G systems.

By providing V2G-capable charging stations today for battery EDVs, utilities are also building portals for V2G for future hybrid and fuel cell vehicles.

The system operator or local utility may not wish to do business with hundreds or thousands of small providers of peak power or ancillary services. In this case, a third party could aggregate EDVs into MW blocks to sell in bulk power and ancillary services markets. At 16 kW per vehicle, a 1 MW block is 63 vehicles. Potential businesses to serve as aggregators include energy service companies (ESCOs), cell-phone operators (accustomed to automated dispatch and billing of millions of individual transactions), telematics service providers working with automobile manufacturers or fleet operators, power marketers, or possibly even service-oriented local distribution companies.

An initial concern often voiced about the V2G concept is that vehicle owners would not want to drain their vehicle's battery or an on board liquid fuel. To avoid V2G being seen as a threat to vehicle range, it is essential that the driver be able to limit any draw down so travel is not affected. Following Kempton and Letendre (1997), that can be done with a control that the driver sets according to driving needs. The power buyer must limit the degree of battery discharge or fuel tank rundown in accordance with the vehicle owners settings. An example control panel is shown in Figure 1. Whether the control is physical, on the dash, or on a Web

Evolution of Propulsion



Source: GM

page, the idea is basically the same. The driver has two parameters to set—the length of the expected next trip (in the case shown in Figure 1, 10 miles at 6:45 the next morning), and the minimum range that must always be maintained, e.g. for an emergency room trip, two miles. (As we will see in Figure 2, when providing regulation up and down rather than peak or spinning reserves, there is little impact on range.)

One conceptual barrier to understanding vehicles as a power source is an initial belief that their power would be unpredictable or unavailable because they would be on the road. Although any one vehicle's plug availability is unpredictable, the availability of thousands or tens of thousands of vehicles is highly predictable and can be estimated from traffic and road-use data. For example, peak late-afternoon traffic occurs during the hours when electric use is highest (from 3-6 p.m.). A supposition one might have from personal experience, that the majority of the vehicles are on the road during rush hour traffic, is false. Based on road use data, we have calculated that over 92 percent of vehicles are parked and thus potentially available to the grid during any given hour, including the peak traffic hours of 3-6 PM (Kempton et al. 2001).

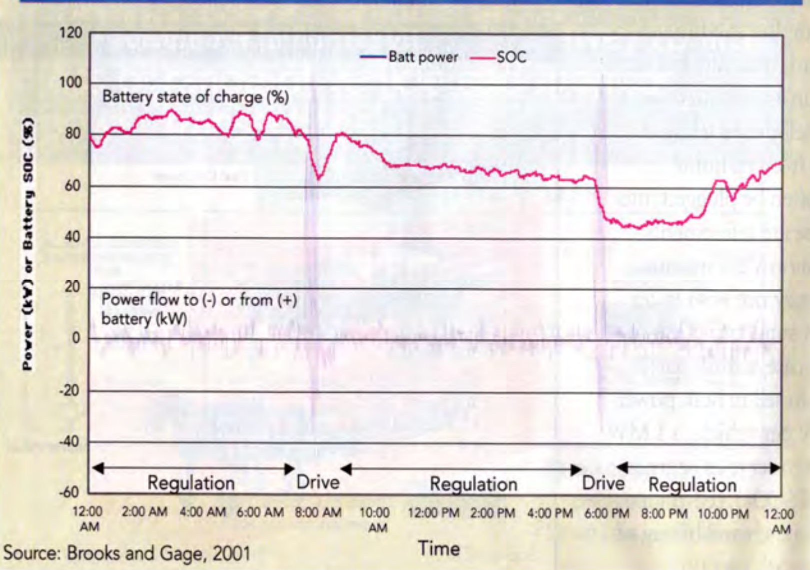
Economic Value of V2G

V2G opportunities and their financial value vary with the type of vehicle and the power market. Battery EDVs can store electricity, charging during low demand times and discharging when power is scarce and prices are high. Of potentially greater value, they can also provide ancillary services, notably regulation up, regulation down, and spinning reserves. Figure 2 illustrates power flow and battery state of charge for a battery EDV being used for regulation up and regulation down. The figure applies to a vehicle used for commuting and that is plugged in at home and work. The two large spikes of power out of the battery at 8 a.m. and 5 p.m. are the commute trip (brief negative driving spikes result from regenerative braking). Since both regulation up and regulation down are provided, the net effect on battery charge is minimal, except after each commute, when regulation is controlled to provide a net charge.

Fuel cell and hybrid EDVs are a somewhat different case than battery powered EDVs in that they represent a new source of power generation. Our earlier analyses suggested that vehicles could not compete for baseload power, but could be competitive when called upon to provide peak power and ancillary services (Kempton and Letendre 1997, 1999; Kempton and Kubo 2000). Consequently, the values reported below derive from V2G in the day-ahead market for power (during peak periods), spinning reserves, and regulation. The values presented here were derived using market-clearing prices in California's competitive electricity markets (but do not rely on prices in the atypical year 2000).

Formulas were derived to calculate the power capacity of each vehicle type. Calculated capacity depends on the charger capacity, residential and commercial electrical service capacity, fuel or electricity needed for the next trip, whether a piped gaseous fuel source is connected to the vehicle,

Figure 2: Power Flow and State of Charge
How an electric vehicle provides regulation services.



Source: Brooks and Gage, 2001

and other factors. All vehicle technical parameters were derived from production or prototype EDVs. The battery vehicles have power capacity on the order of 10 kW and fuel cell vehicles have up to approximately 40 kW. The hybrid vehicles are of interest when operating in the motor-generator mode, fueled by gasoline or a natural gas line, with power capacity up to 30 kW. For many scenarios, output is limited by line capacity to the existing 6 kW charging stations (Level 2), or near term standards that allow 16 kW (Level 3AC charger).

A key element regarding the economics of V2G is the cost of electricity generated by each EDV type. We calculate that battery vehicles can provide electricity to the grid at a cost of $0.23/kWh for current lead-acid batteries, $0.45/kWh for the Honda EV Plus with nickel metal hydride (NiMH) batteries, and $0.32/kWh for the Th!nk City car with nickel cadmium (NiCd) battery. The fuel cell vehicle can generate electricity at a cost ranging between $0.09—$0.38 kWh, the wide range being due to the projected costs of H_2, with the lower figure based on the longer-term assumption of a mature hydrogen market. A fuel cell vehicle with hydrogen recharge through a garage reformer could generate electricity at $0.19/kWh from natural gas (at $0.84/therm). The hybrid vehicles in motor-generator mode can generate electricity at a cost of $0.21/kWh if fueled with gasoline (at $1.50 per gallon) and at $0.19/kWh if fueled with natural gas. Based only on these simple costs per kWh, it appears that in the near term the most attractive EDV types are the lead-acid battery vehicles, a fuel cell vehicle recharged from a natural gas reformer, and the hybrid vehicle. However, to understand the best niche for V2G power, the simple per kWh cost comparison is inadequate.

The cost of electricity from the EDVs noted above is too high to be competitive with baseload power. However, EDV power could be competitive in three other markets: peak power, spinning reserves,

Hydrogen Power: A New Initiative, a New Fuel Cell Car

Against a backdrop of futuristic vehicles at the Detroit Auto Show, Secretary of Energy Spencer Abraham and executives of Ford, General Motors and DaimlerChrysler in early January announced a new cooperative automotive research partnership between the DOE and the U.S. Council for Automotive Research (USCAR). The new public-private partnership will promote the development of hydrogen as a primary fuel for cars and trucks, as part of U.S. efforts to reduce dependence on foreign oil.

Of those futuristic vehicles, General Motors unveiled its Autonomy fuel cell car, which it says is the first vehicle designed exclusively for the fuel cell. After a century of making gasoline-burning cars, General Motors sees a not-so-distant future when vehicles powered by hydrogen will revolutionize the industry and make transportation more affordable for the world's population.

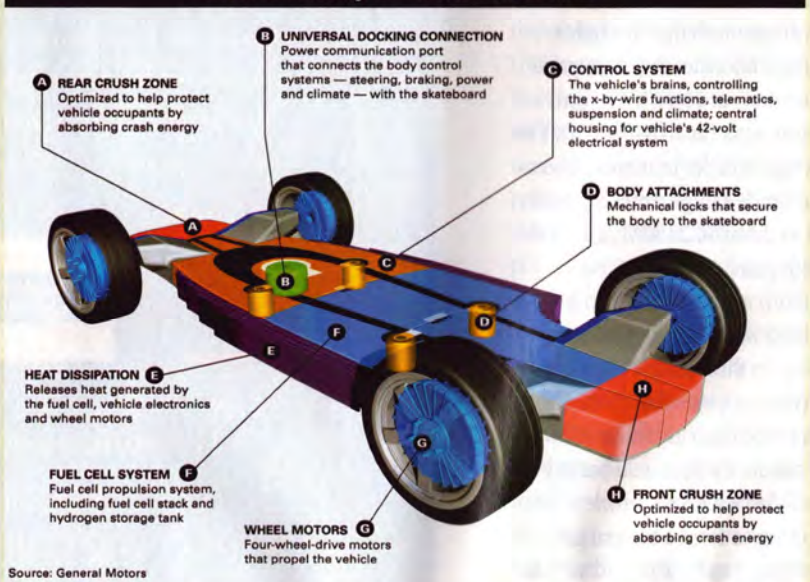
Because fuel cells consume hydrogen and emit only water and heat, automakers have talked for years about the arrival of the cleaner technology over the next decade as a way to make cars more environmentally friendly and curtail the need for foreign oil.

The Autonomy houses all the essential elements of the car, including the fuel cell to provide power, in a skateboard-like chassis between the four wheels and under the body and seats of the vehicle. The chassis could be fitted with a wide variety of bodies, such as a minivan interior for a family in the United States, or a pickup truck bed for hauling livestock in China, General Motors says.

Because the Autonomy chassis has a 20-year lifespan, a growing family could change from a sporty sedan to a larger sport utility vehicle simply by switching the body, a far cheaper alternative to buying a new vehicle. Or, if the vehicle needs more power, the fuel cell can be expanded.

A vehicle using the Autonomy chassis could look completely different from those on the road today. Because the gasoline-burning engine is gone and all the controls, such as steering and braking, are operated by electronic wires rather than mechanical connections, car designers are free to come up with new interpretations of cars and trucks. —R.S.

Autonomy's "Skateboard"



Source: General Motors

and regulation services. The latter two electricity markets are called "ancillary services," and in each, the power producer is paid a contract price for being connected and available, in addition to per kWh energy payments. Grid operators maintain reserve generating capacity available for immediate power production. The term "spinning" reserves refers to generators spinning and synchronized with the grid, ready for immediate power feed into the grid. Typically, these reserves are called upon when a power plant drops off-line unexpectedly due to equipment failure. By contrast, regulation is needed throughout the day and night. Grid operators must continuously match the generation of power to the consumption. Regulation requires a generating facility that can ramp power up or down under real time control of the grid operator.

In California and a few other power markets, this function, called regulation or automatic generation control (AGC), is unbundled from power generation, and is sold separately. Even when provided internally to a company, regulation has costs—at a minimum, generators must be kept at idle or partial speed.

For each combination of vehicle and power market, we calculate the value of the power in California's electricity markets and the cost to the vehicle owner for providing power, assuming V2G power is produced only when revenue will exceed cost. This method is more comprehensive than earlier methods that used avoided costs (Kempton and Letendre 1997) or retail time-of-use rates (Kempton and Kubo 2000). Other benefits, including reduced air pollution, increased reliability of the electric system, and other distributed benefits (i.e., reduced line losses and avoidance of transmission and distribution upgrades) are not included in the economic calculations, nor are transaction costs. Calculation of vehicle owner costs is comprehensive, including capital costs of any additional equipment required, fuel, and shortening of battery pack and internal

Fuel cell and hybrid EDVs are a somewhat different case than battery powered EDVs in that they represent a new source of power generation.

Table 1: Vehicle owner's annual net profit from V2G

These are representative mid-range figures extracted from full analysis in the report.

	Peak power	Spinning reserves	Regulation services
Battery, full function	$267 (510—243)	$720 (775—55)	$3,162 (4479—1317)
Battery, city car	$75 (230—155)	$311 (349—38)	$2,573 (4479—1906)
Fuel cell, on board H_2	$-50 (loss) to $1,226 (2200—974 to 2250)	$2,430 to $2,685 (3342—657 to 912)	$-2,984 (loss) to $811 (2567—1756 to 5551)
Hybrid, gasoline	$322 (1500—1178)	$1,581 (2279—698)	$-759 (loss) (2567—3326)

Source: Kempton et al, 2001

combustion engine lifetime due to additional use.

Some key V2G economic results are summarized in Table 1. From Table 1, one notices that some vehicles are better suited than others for individual power markets. Matching the vehicle type to power market is important, as it is possible to both gain and lose money.

Taking the three markets in turn, peak power is the least promising. In our model, battery-powered vehicles serve the peak power market by charging their batteries during off-peak hours when price is low (e.g., 4.5 ¢/kWh) and selling power to the grid when the price is high (e.g., over 30 ¢/kWh). The fueled vehicles sell peak power when power prices are above the costs to produce power. Although the table shows potential profits by the historical rule of thumb, for two of the three years of actual market prices from California's now defunct Power Exchange, we find that the price was never high enough to justify selling electricity in the bulk power market during peak price periods.

Spinning reserves shows economic viability for most vehicles we analyzed, and for all those shown in Table 1. Net revenues for the spinning reserve market is particularly large for the fueled vehicles and is relatively insensitive to fuel prices because a large portion of the revenue stream is from contract payments for time available, rather than for power generated.

Regulation services involve higher numbers, for both revenue and cost, because vehicles can sell regulation more of the time. The battery vehicles appear to be especially suitable for regulation. This is because regulation demands shallower cycling than peak or spinning reserves, thus causing less battery degradation. Also, batteries experience very little net discharge when providing both regulation up and regulation down. The estimated net value of regulation services from battery EDVs is several thousand dollars per year. Fuel cell vehicles and hybrids in motor-generator mode could provide only regulation up, not down, and the economics are not attractive.

Vehicles can provide ancillary services of a higher quality than currently available—fast response, available in small increments, and distributed. In a recent presentation, California Independent System Operator (ISO) staff described several possible advantages of V2G over current methods: Fast response to AGC signals, improved frequency control, less wear and tear on generators, and the possibility of frequency response service and line overload relief (Hawkins 2001). Possible concerns to study include the impact on distribution systems, making V2G visible to the EMS system, and generally, the lack of experience of system operators with distributed resources. An additional consideration by the Califonia ISO is that V2G appears to be "an ideal complement to wind generation," since the regulation function of battery EDVs can be used to smooth out small or unexpected fluctuations in wind power production (Hawkins 2001). Thus, the demand for and value of V2G grid services may increase in the future, as intermittent, renewable energy resources become a larger fraction of electric generation.

Over just a decade or two, V2G could revolutionize the ancillary services market, improve grid stability and reliability, and support increased generation from intermittent renewables.

As the V2G-capable EDV fleet grows, it will begin to saturate existing ancillary service markets. We estimate that in California the market for regulation services, the highest value market, could be met with 109,000 to 174,000 vehicles, and spinning reserves with an additional 76,000 to 273,000 vehicles. Peak power could be a still larger market, but only at lower V2G costs than we currently project. These vehicle saturation numbers represent a small fraction of the total vehicle fleet in California, but they should be sufficient to stimulate more than a decade of projected sales, past the time that production volumes bring down EDV sticker prices.

Conclusions

Overall, we conclude that all three types of EDVs—battery, hybrid, and fuel cell—could become a significant component of the nation's electric grid. The largest value is in ancillary services such as spinning reserves and regulation. For battery and fuel cell vehicles, and possibly plug-in hybrids, the net value of this power is over $2,000 annually per vehicle, enough to quickly and economically usher in the era of a low- and zero-pollution light vehicle fleet.

Several policy issues are raised by this analysis. Initially, demonstration projects would help answer questions which are not amenable to the modeling approach presented here. Also, some policy review would be helpful now. From the electric industry side, it would be appropriate to review rate structures and interconnect and safety standards in order to assess changes or additions appropriate for V2G power. Interconnection standards are currently being addressed to accommodate emerging distributed energy technologies (e.g., photovoltaics, stationary fuel cells, and micro-turbines). Charging station infrastructure planning should similarly be reviewed for its application to V2G power (as CARB has already done for California).

Individual utilities acquiring electric-drive vehicle fleets might start by reviewing their buying specifications. With the low incremental cost of adding V2G at the design stage—and with products already on the market—now may be the time to add V2G as a specification for new purchases. Utilities may start to ask, why not have our fleet of customer service or meter-reader vehicles providing regulation services while parked? If experience with utility-fleet vehicles providing V2G is positive, the next questions might be: How much vehicle ancillary service do we want to acquire in total? Do we want an aggregator to sell us MW blocks, or is aggregation an interesting opportunity for one of our business units?

Over just a decade or two, V2G could revolutionize the ancillary services market, improve grid stability and reliability, and support increased generation from intermittent renewables. The associated revenue stream could make electric-drive vehicles more attractive to buyers. These synergistic developments could have substantial benefits to the electric industry, to the environment, and to society as a whole. F

Steven Letendre is a professor of management and environmental studies at Green Mountain College in Poultney, VT. He has worked as a utility economist at the Research Triangle Institute in North Carolina, and is the author of numerous articles on distributed generation and economics and electric utility policy. Willett Kempton teaches and conducts research on environmental policy at the University of Delaware. He is senior policy scientist in the university's Center for Energy and Environmental Policy, and is an associate professor in the College of Marine Studies.

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Acknowledgments

This article draws from a report sponsored by the California Air Resources Board (CARB) and the Los Angeles Department of Water and Power (LADWP). This report is available in PDF (Portable Document Format) at the our web site, which also has other documents and resources on vehicle-to-grid power, http://www.udel.edu/V2G. We would like to acknowledge our collaborators on the CARB/LADWP project: Jasna Tomic, University of Delaware; Alec Brooks and Tom Gage, AC Propulsion, and Timothy Lipman, University of California, Berkeley and Davis. Notification: The statements and conclusions in this article based on the above-cited report are those of the contractor and not necessarily those of the California Air Resources Board, and the mention of commercial products, their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Appendix IA01

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PDF Version of this guide

Getting Started

Be sure to choose the search type you want **before** you begin your search.

· Choose **BROWSE** for an exact title, journal title, series, or LCS heading.
· Choose **KEYWORD** for searching topics.
· Choose **QUICK SEARCH** for simple keyword searches on unique words or phrases.
· Choose **CALL NUMBER** for browsing by call number within a Library or collection.

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I. Click the **Browse** Tab to Search for a ***specific title*** of a book, journal, or series.

II. Follow the four steps outlined on the screen.

1. Choose either ***Beginning With*** (enter the first words of the title) or ***Exact*** (enter the exact title, etc.). Remember: The computer searches your words sequentially.
2. Type the title of the item. ***Leave off all leading articles (A, AN, THE).***
3. Choose a Library. It is usually best to use "ALL" Libraries.
4. Click one of the options. This will both choose your search type and execute the search.

(for a book, document, or videotape)
(for a newspaper, magazine, or journal)
(for a series)

Example

Searching for an Author

I. Click the **Browse** Tab to Search for a specific author.

II. Follow the four steps outlined on the screen.

1. Choose ***Beginning With***. Remember: Word order matters here!
2. Type the author of the item, **last name first**. (Example: shakespeare, william)
3. Choose a Library. It is usually best to use "ALL" Libraries.
4. Click **Author** to execute an author search.

Example

Searching for a Topic (Keyword or Subject)

The default in the Enhanced CAT (the first search screen) is for topic or keyword searching.

I. Type words on one or more lines. (If you use more than one line choose the appropriate connector-AND, OR, NOT-from the drop down menu on the right.)
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Keywords anywhere finds records containing the words or phrases you request in any of these parts of the record (Author, Title, LC Subject, Series, Notes).
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IV. Click the button.

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Other Features of the CAT		Punctuation Marks
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Use to navigate in The CAT. Using the browser buttons may create problems.		$ Replaces any number of characters. For example, **environment$** retrieves environment, environments, environmental, and environmentally.
when you finish, especially if you placed a recall or looked at your library record.	?	? Must replace one, and only one, character. For example, **wom?n** retrieves woman or women.
button will take you to the main LIAS page. From here, you may access the Fast Track list of databases.	' '	PHRASE SEARCHING To search for a phrase on the keyword page, enclose the phrase in single quotes. **'women engineers'** will retrieve the exact phrase, otherwise the words will be retrieved from anywhere in the same field in any order.
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Keyword search page.

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Appendix FERNANDEZ01

US007374003B1

(12) **United States Patent**
Fernandez

(10) **Patent No.:** **US 7,374,003 B1**
(45) **Date of Patent:** **May 20, 2008**

(54) **TELEMATIC METHOD AND APPARATUS WITH INTEGRATED POWER SOURCE**

(76) Inventor: **Dennis S. Fernandez**, 1175 Osborn Ave., Atherton, CA (US) 94027

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 407 days.

(21) Appl. No.: **11/288,724**

(22) Filed: **Nov. 28, 2005**

Related U.S. Application Data

(63) Continuation of application No. 10/626,877, filed on Jul. 23, 2003.

(51) **Int. Cl.**
B60L 1/00 (2006.01)

(52) **U.S. Cl.** **180/65.8**; 701/22

(58) **Field of Classification Search** 180/65.1, 180/65.2, 65.3, 65.4, 65.5, 65.8; 701/22
See application file for complete search history.

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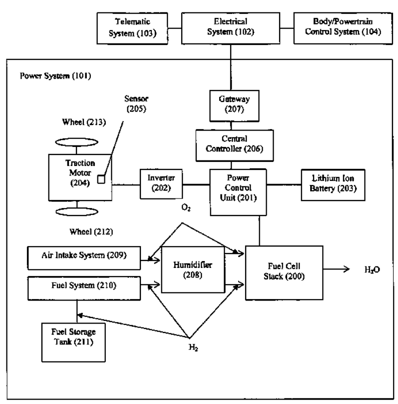
Primary Examiner—Christopher Ellis
Assistant Examiner—John D Walters
(74) *Attorney, Agent, or Firm*—Fernandez & Associates, LLP

(57) **ABSTRACT**

Telematic method and apparatus adaptively uses fuel cell power source in vehicle with integrated power system, electrical system, telematic system, and body/powertrain system. Telematic communications systems including internet, digital video broadcast entertainment, digital audio broadcast, digital multimedia broadcast, global positioning system navigation, safety services, intelligent transportation systems, and/or universal mobile telecommunications system. Network-accessible software enables integrated modular function for automated control and provision of fuel cell resources for telematic appliance and/or other vehicle electro-mechanical devices.

1 Claim, 14 Drawing Sheets



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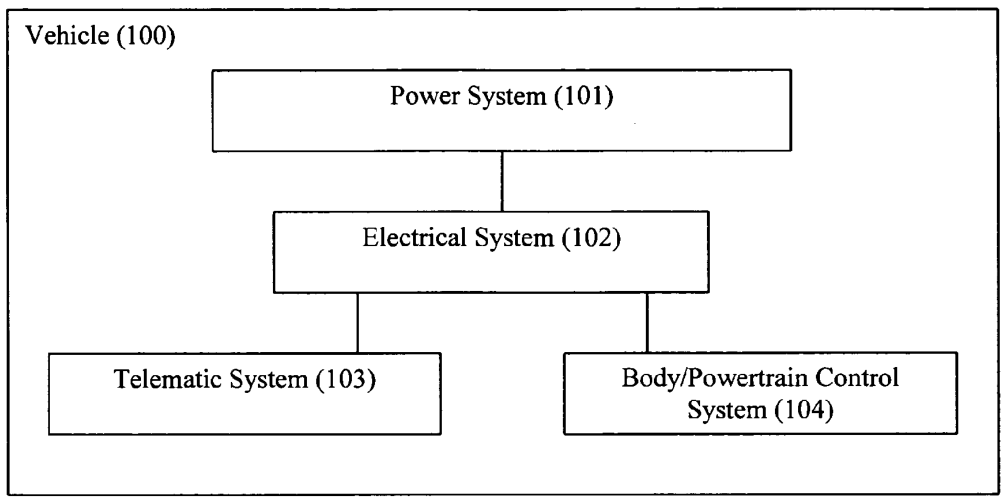

Vehicle (100)
Power System (101)
Electrical System (102)
Telematic System (103)
Body/Powertrain Control System (104)

FIGURE 1

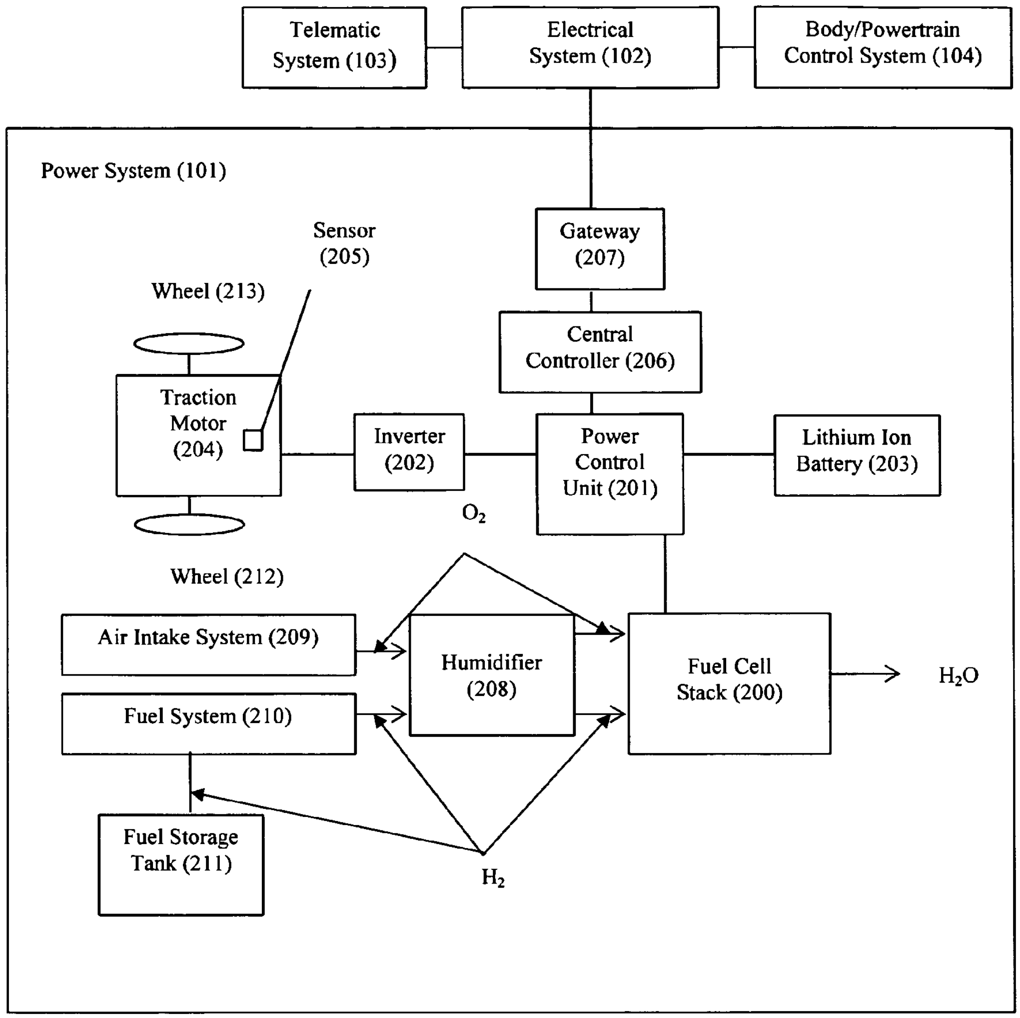

Telematic System (103)
Electrical System (102)
Body/Powertrain Control System (104)
Power System (101)
Sensor (205)
Gateway (207)
Wheel (213)
Central Controller (206)
Traction Motor (204)
Inverter (202)
Power Control Unit (201)
Lithium Ion Battery (203)
O_2
Wheel (212)
Air Intake System (209)
Humidifier (208)
Fuel Cell Stack (200)
H_2O
Fuel System (210)
Fuel Storage Tank (211)
H_2

FIGURE 2A

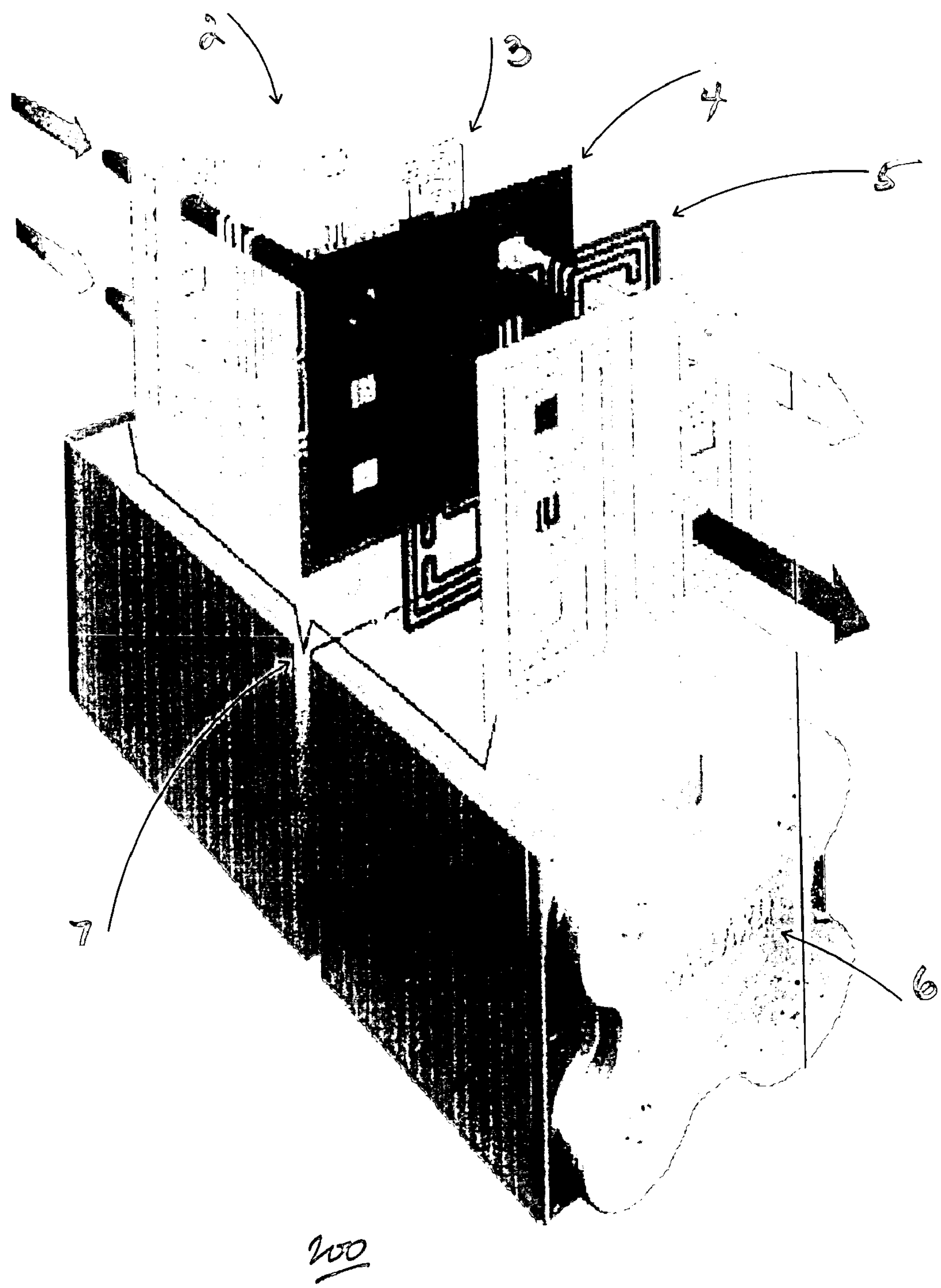


FIGURE 2B

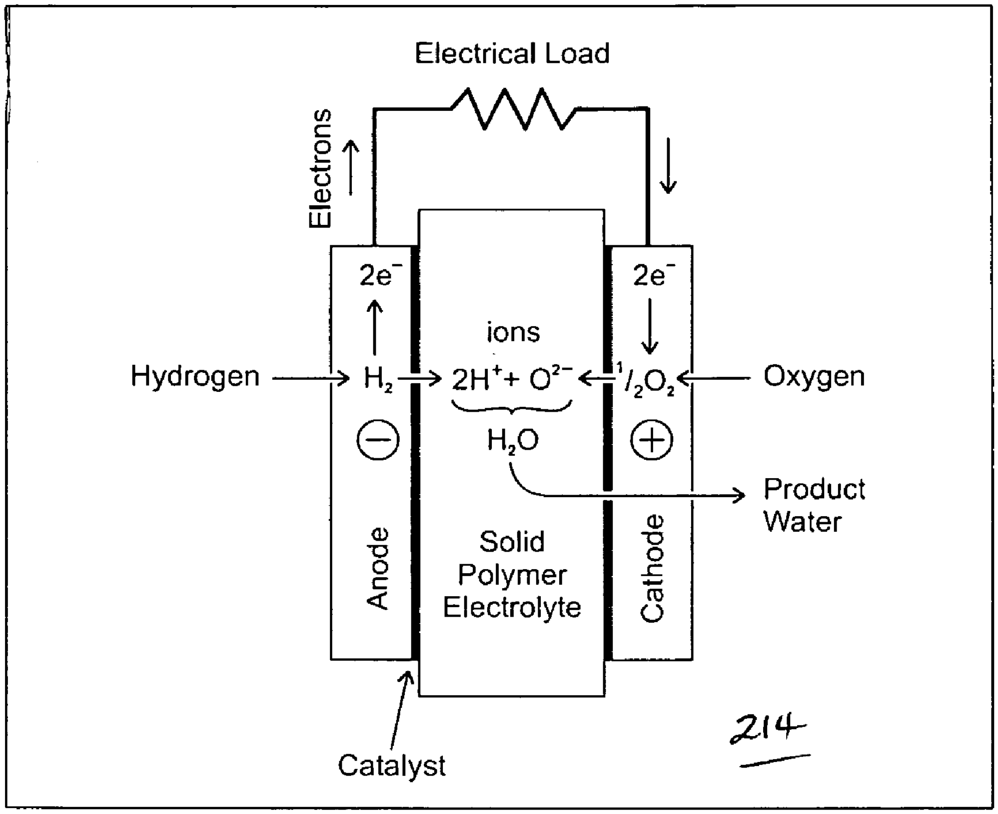

Electrical Load
Electrons
2e⁻
2e⁻
ions
Hydrogen
H_2
$2H^+ + O^{2-}$
$^1/_2O_2$
Oxygen
H_2O
Product
Water
Anode
Solid
Polymer
Electrolyte
Cathode
Catalyst
214

FIGURE 2C

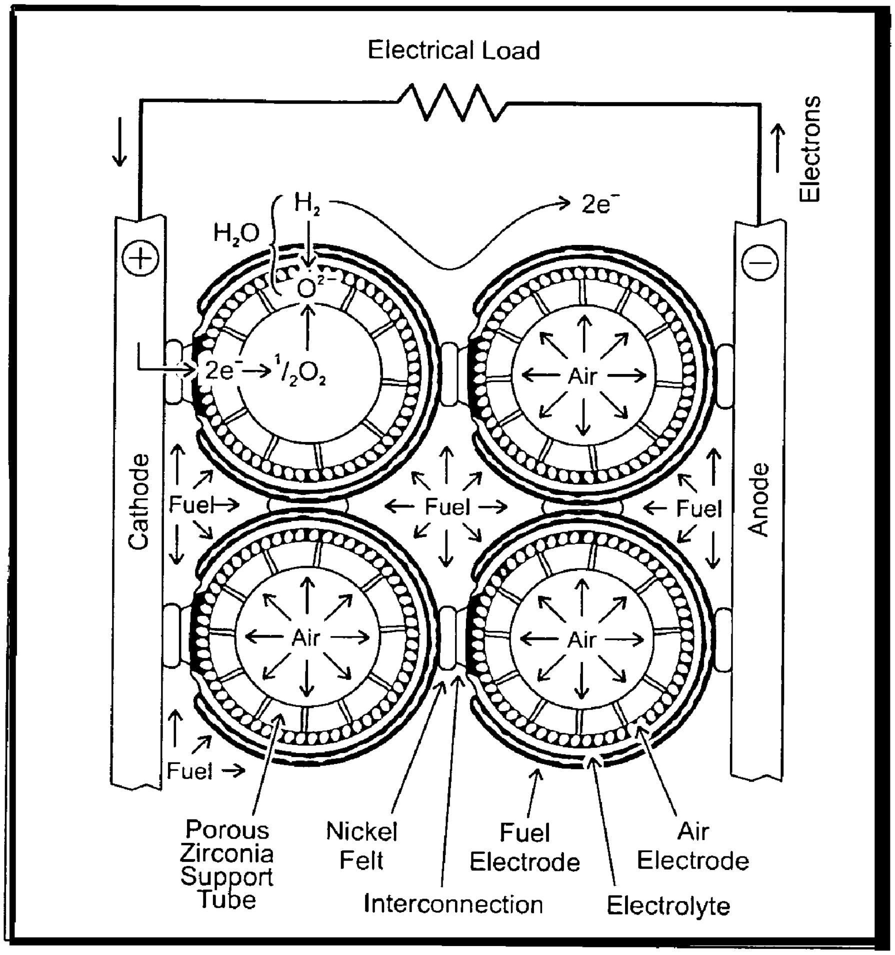

Electrical Load
Electrons
H2
H2O
2e-
O2-
2e- → 1/2O2
Air
Air
Air
Fuel
Fuel
Fuel
Fuel
Cathode
Anode
Porous Zirconia Support Tube
Nickel Felt
Fuel Electrode
Air Electrode
Interconnection
Electrolyte

FIGURE 2D

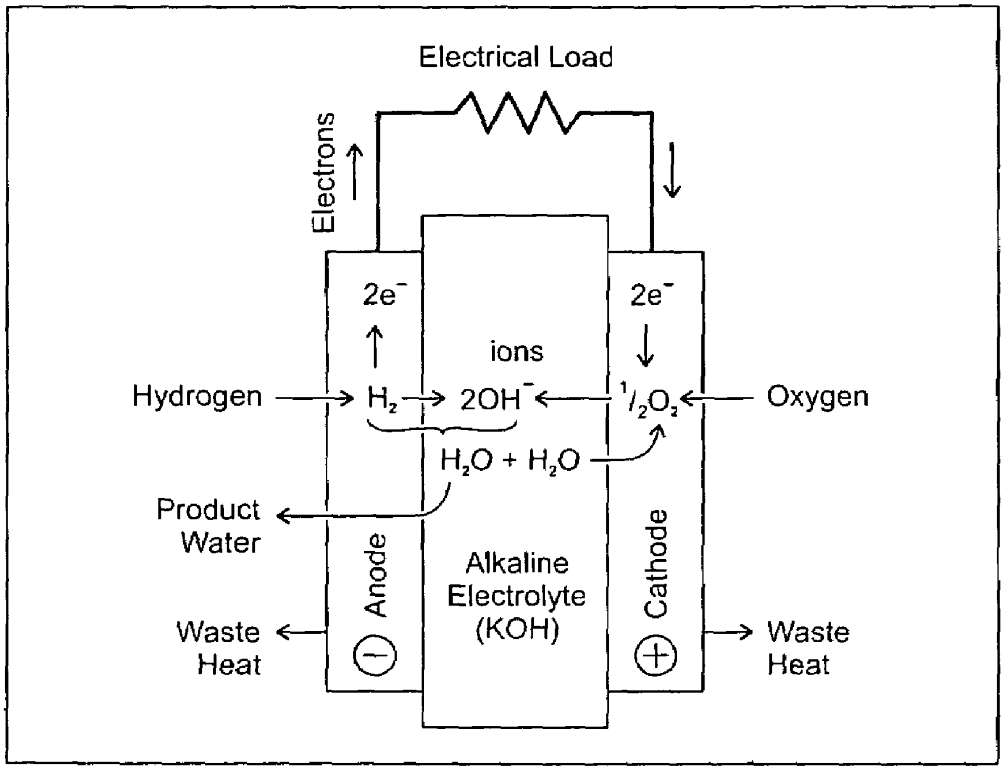
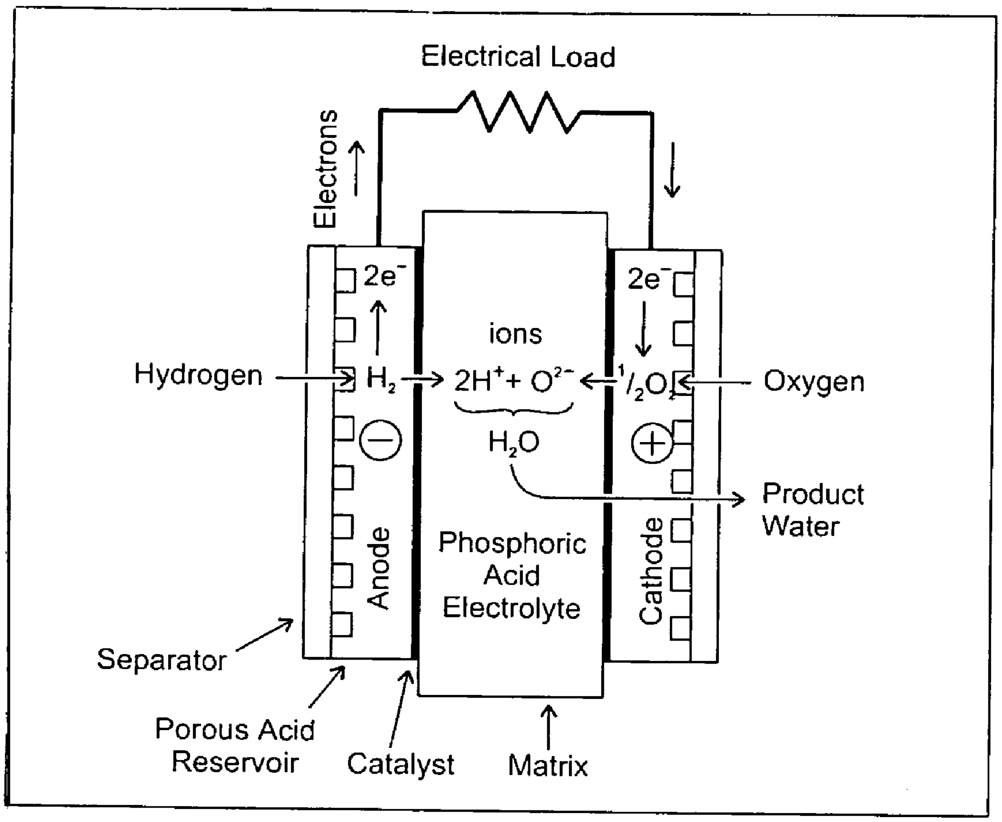

Electrical Load
Electrons
2e⁻
2e⁻
ions
Hydrogen
H2
2OH⁻
1/2O2
Oxygen
H2O + H2O
Product
Water
Anode
Alkaline
Electrolyte
(KOH)
Cathode
Waste
Heat
Waste
Heat

FIGURE 2E



Electrical Load
Electrons
2e⁻
2e⁻
ions
Hydrogen
H₂
2H⁺+ O²⁻
½O₂
Oxygen
H₂O
Product
Water
Anode
Phosphoric
Acid
Electrolyte
Cathode
Separator
Porous Acid
Reservoir
Catalyst
Matrix

FIGURE 2F

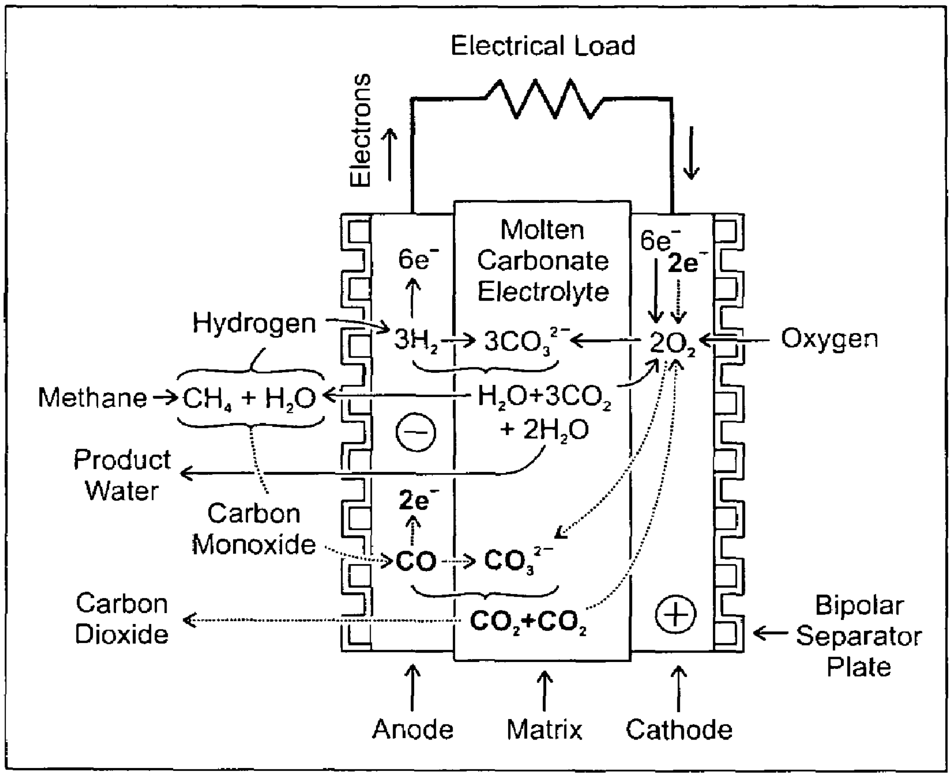

Electrical Load
Electrons
Molten
Carbonate
Electrolyte
6e⁻
6e⁻
2e⁻
Hydrogen
3H₂
3CO₃²⁻
2O₂
Oxygen
Methane
CH₄ + H₂O
H₂O+3CO₂
+ 2H₂O
Product
Water
Carbon
Monoxide
2e⁻
CO
CO₃²⁻
Carbon
Dioxide
CO₂+CO₂
Bipolar
Separator
Plate
Anode
Matrix
Cathode

FIGURE 2G

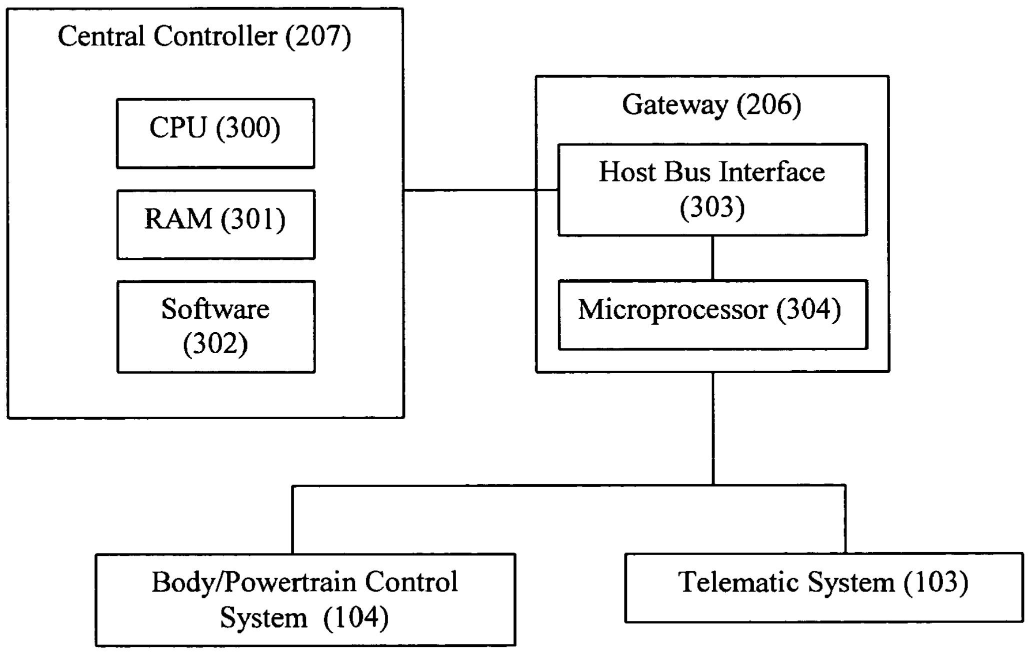

Central Controller (207)
CPU (300)
RAM (301)
Software (302)
Gateway (206)
Host Bus Interface (303)
Microprocessor (304)
Body/Powertrain Control System (104)
Telematic System (103)

FIGURE 3

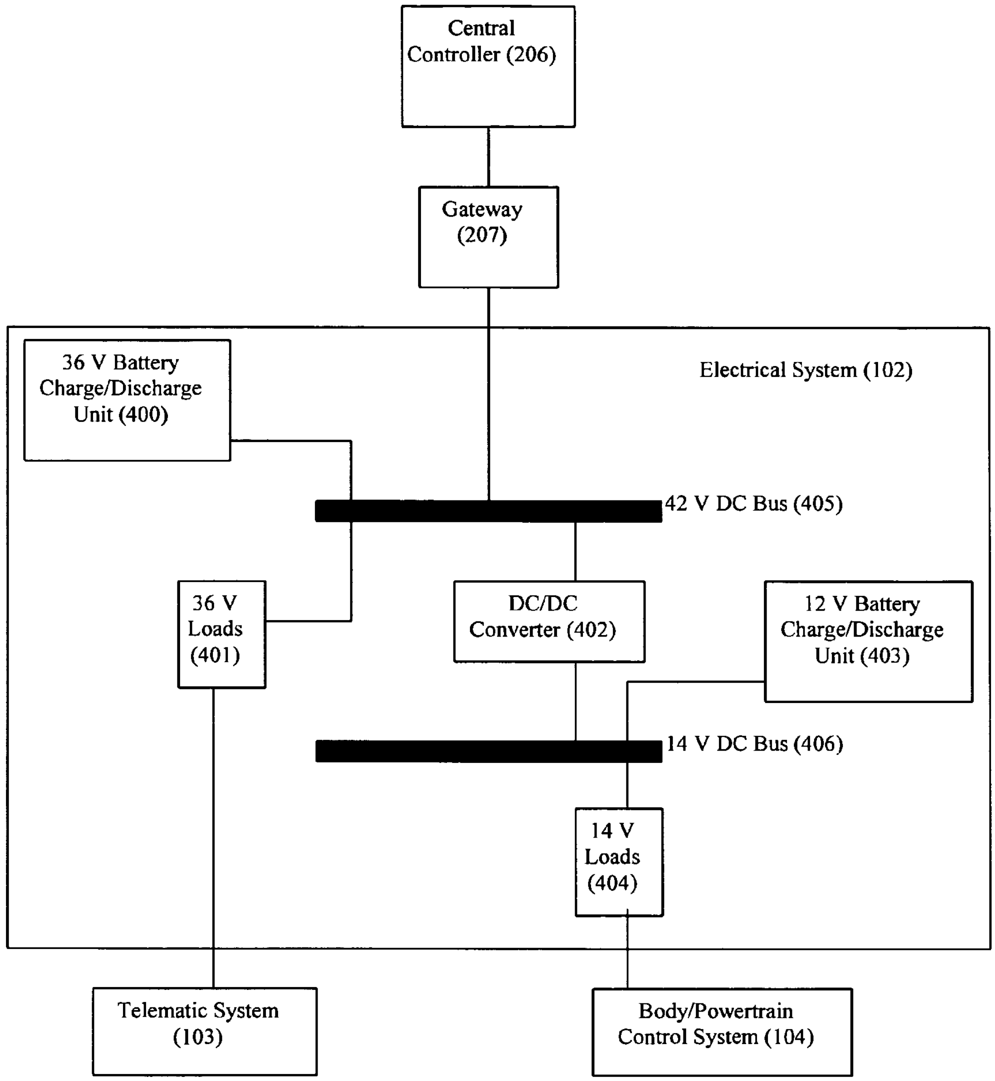

Central
Controller (206)
Gateway
(207)
36 V Battery
Charge/Discharge
Unit (400)
Electrical System (102)
42 V DC Bus (405)
36 V
Loads
(401)
DC/DC
Converter (402)
12 V Battery
Charge/Discharge
Unit (403)
14 V DC Bus (406)
14 V
Loads
(404)
Telematic System
(103)
Body/Powertrain
Control System (104)

FIGURE 4

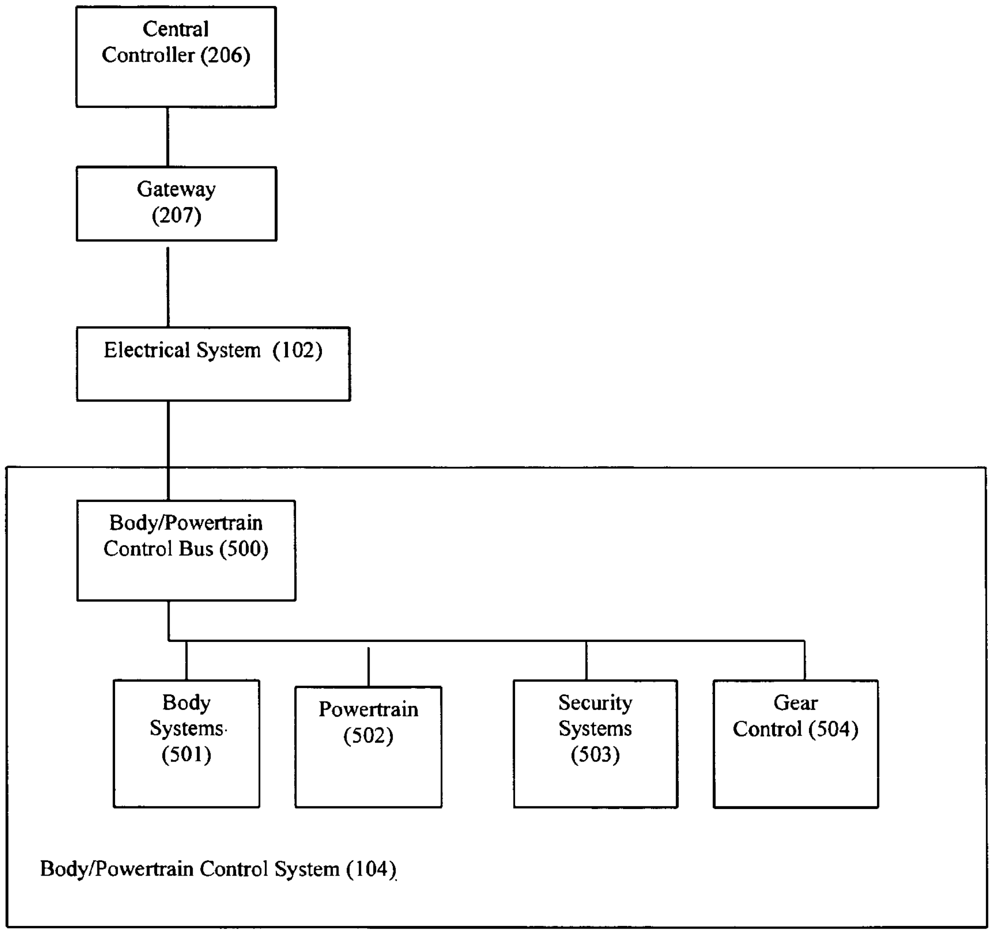

Central
Controller (206)
Gateway
(207)
Electrical System (102)
Body/Powertrain
Control Bus (500)
Body
Systems
(501)
Powertrain
(502)
Security
Systems
(503)
Gear
Control (504)
Body/Powertrain Control System (104)

FIGURE 5

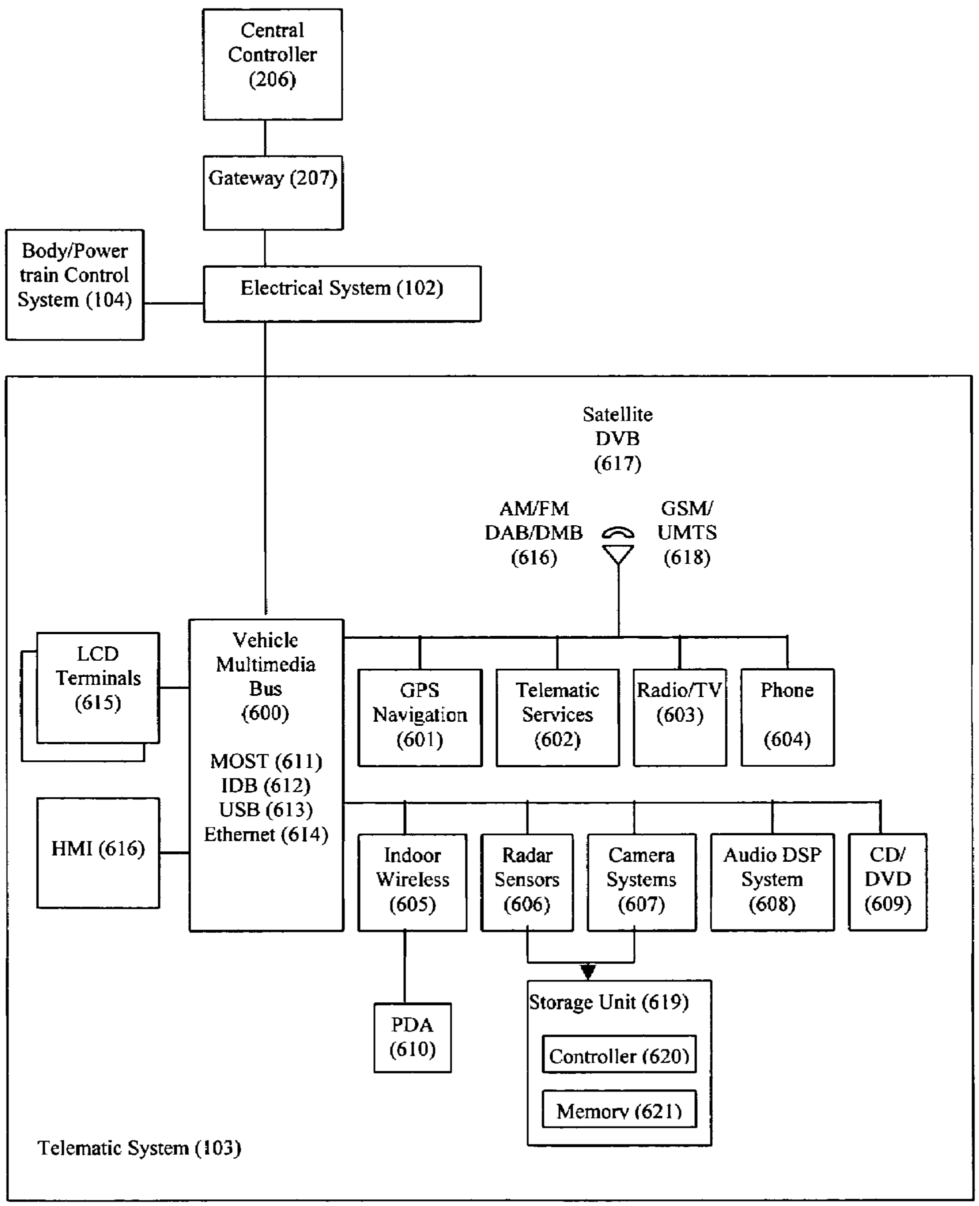

Central Controller (206)
Gateway (207)
Body/Power train Control System (104)
Electrical System (102)
Satellite DVB (617)
AM/FM DAB/DMB (616)
GSM/ UMTS (618)
LCD Terminals (615)
Vehicle Multimedia Bus (600)
MOST (611)
IDB (612)
USB (613)
Ethernet (614)
GPS Navigation (601)
Telematic Services (602)
Radio/TV (603)
Phone (604)
HMI (616)
Indoor Wireless (605)
Radar Sensors (606)
Camera Systems (607)
Audio DSP System (608)
CD/ DVD (609)
PDA (610)
Storage Unit (619)
Controller (620)
Memory (621)
Telematic System (103)

FIGURE 6

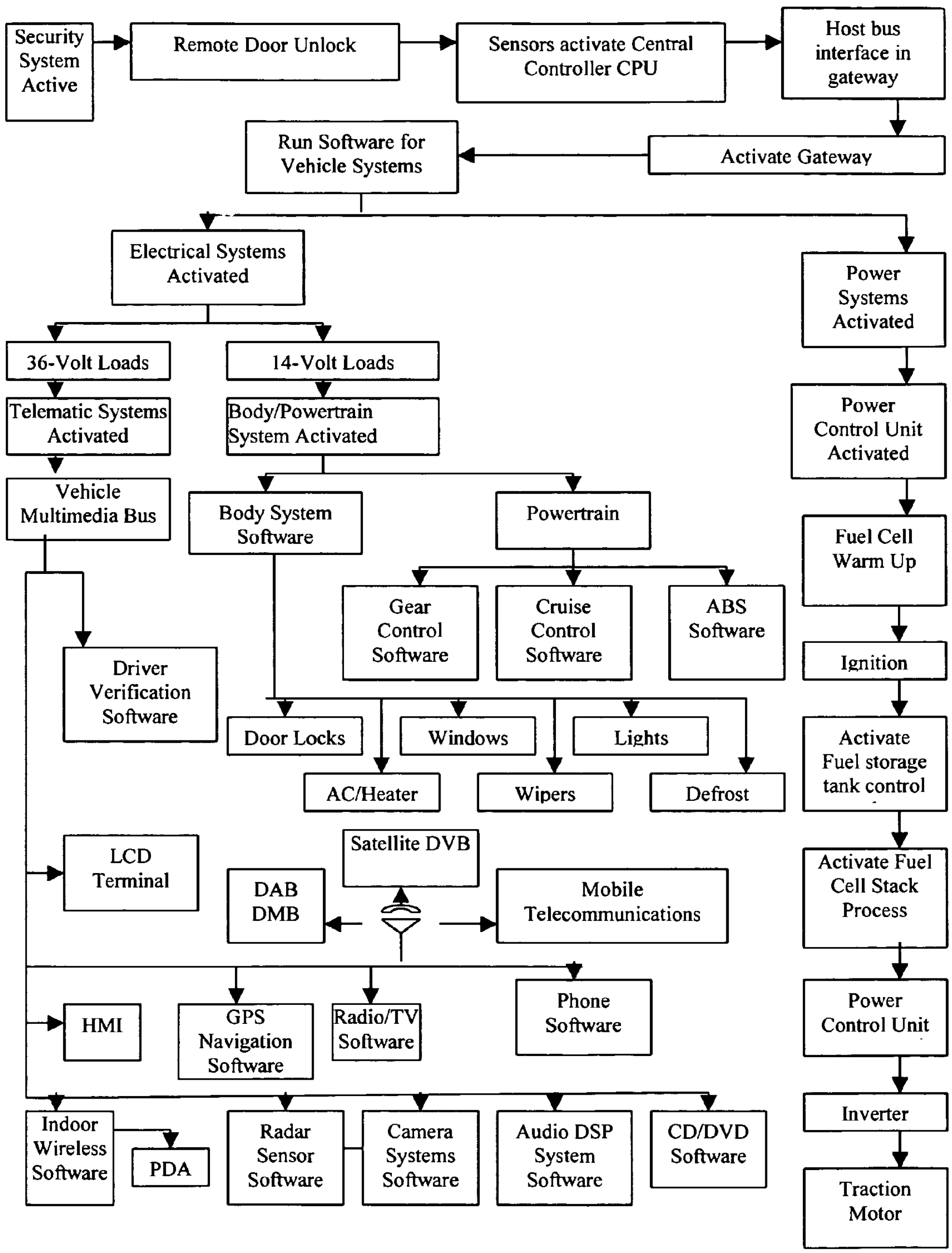

Security System Active
Remote Door Unlock
Sensors activate Central Controller CPU
Host bus interface in gateway
Activate Gateway
Run Software for Vehicle Systems
Electrical Systems Activated
Power Systems Activated
36-Volt Loads
14-Volt Loads
Telematic Systems Activated
Body/Powertrain System Activated
Vehicle Multimedia Bus
Body System Software
Powertrain
Power Control Unit Activated
Fuel Cell Warm Up
Gear Control Software
Cruise Control Software
ABS Software
Driver Verification Software
Ignition
Door Locks
Windows
Lights
AC/Heater
Wipers
Defrost
Activate Fuel storage tank control
LCD Terminal
Satellite DVB
DAB DMB
Mobile Telecommunications
Activate Fuel Cell Stack Process
HMI
GPS Navigation Software
Radio/TV Software
Phone Software
Power Control Unit
Inverter
Indoor Wireless Software
PDA
Radar Sensor Software
Camera Systems Software
Audio DSP System Software
CD/DVD Software
Traction Motor

FIGURE 7

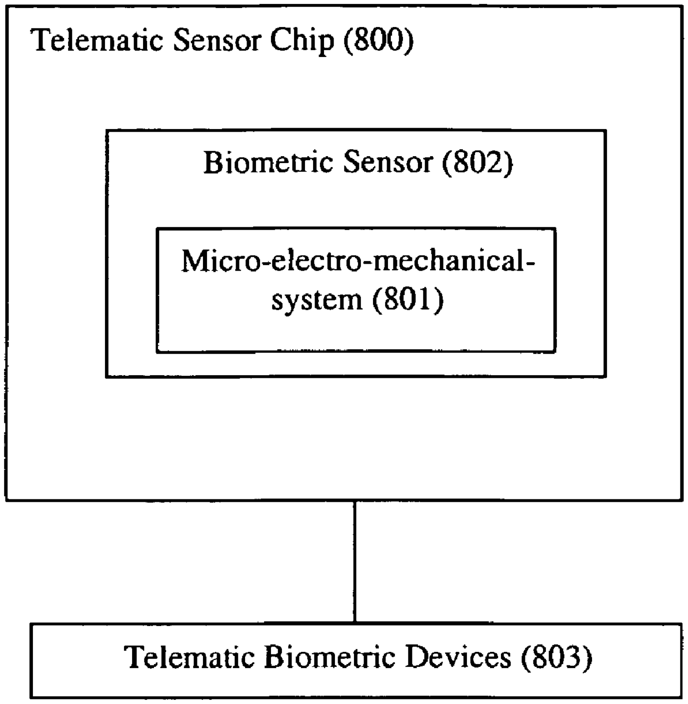

Telematic Sensor Chip (800)
Biometric Sensor (802)
Micro-electro-mechanical-system (801)
Telematic Biometric Devices (803)

FIGURE 8

TELEMATIC METHOD AND APPARATUS WITH INTEGRATED POWER SOURCE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of the U.S. patent application Ser. No. 10/626,877 filed on Jul. 23, 2003.

BACKGROUND

1. Field of Invention

Invention relates to telematic devices and processing method integrated adaptively with a power source and sensors, particularly in fuel cell vehicle applications.

2. Related Art

Conventional power systems in vehicles such as automobiles rely on mechanical energy as primary power sources for vehicle systems. These systems include the growing number of telematic applications in vehicles including Internet, digital video broadcast entertainment, digital audio broadcast, digital multimedia broadcast, global positioning system navigation, safety services, intelligent transportation systems, and universal mobile telecommunications system.

The advent of fuel cell technology has initiated the genesis of a change in standard from the combustion engine in vehicles to vehicle engines powered by fuel cells. Similarly, a new industry standard has emerged that calls for a 42-volt electrical vehicle system as opposed to the conventional 12 to 14 volt electrical system. This transformation is due to higher electrical loads that vehicles face as a result in higher demands of hotel loads such as onboard computing navigation, electronically heated seats, video entertainment systems, and other telematic devices, along with the traditional electrical requirements for the body/powertrain control branch of the vehicle that includes throttle actuation, steering, active suspension and ride height adjustment, electric air conditioning, and electrically heated catalyst.

Unlike conventional vehicles with internal combustion engines that use mechanical energy as a primary source of power, fuel cell vehicles require greater on-board electric power to run the traction motor and increasing number of telematics in addition to the standard body/powertrain control components. Accordingly, there is need for an integrated telematic system in fuel cell vehicles that derive the necessary power requirement from on-board electric power sufficient to for electric requirements.

SUMMARY

Telematic apparatus with integrated power source in a vehicle utilizes a fuel cell as a primary source of power for the traction motor. The vehicle includes an integrated network comprising a power system, an electrical system, a telematic system, and a body/power train control system. These integrated systems are adaptively controlled by one or more microprocessors run by programmable software functions that allow a user to operate the vehicle using telematics and multimedia networks.

Central controller is a core element of this electro-mechanical vehicle scheme, and distributes and manages electricity preferably in a 42-volt system. The controller serves as a multimedia center for the user to control both electronic and mechanical segments of the vehicle through a gateway. Its main task is to control the user interaction with the system and serve as a front-end for many electronic control units. These units include telematic components in the vehicle such as wireless internet, digital video broadcast entertainment, digital audio broadcast, digital multimedia broadcast, global positioning system navigation, safety services, intelligent transportation systems, and universal mobile telecommunications system.

In order to communicate with the electronic control units, the central controller has access to one or more buses through a gateway controller, which acts as a router, switch or other selectable signal interconnect between various electrical buses in the vehicle. The control area network and local interconnect network protocol enable communication between electronic control units in the vehicle systems. The telematic systems use a media oriented systems transport, intelligent transportation system data bus and universal serial buses to connect to the gateway.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a simplified system diagram showing vehicle subsystems according to an embodiment of the present invention.

FIG. **2***a* is functional diagram illustrating the vehicle power system according to an embodiment of the present invention.

FIG. **2***b* is a diagram illustrating a fuel cell stack according to an embodiment of the present invention.

FIG. **2***c* is a diagram illustrating a proton exchange membrane fuel cell according to an embodiment of the present invention.

FIG. **2***d* is a functional diagram illustrating tubular-design solid oxide fuel cell according to an embodiment of the present invention.

FIG. **2***e* is a functional diagram illustrating alkaline fuel cell according to an embodiment of the present invention.

FIG. **2***f* is a functional diagram illustrating phosphoric acid fuel cell according to an embodiment of the present invention.

FIG. **2***g* is a functional diagram illustrating molten carbonate fuel cell according to an embodiment of the present invention.

FIG. **3** is a block diagram illustrating interaction between the gateway and the vehicle central controller according to an embodiment of the present invention.

FIG. **4** is a block diagram illustrating the vehicle electrical subsystem according to an embodiment of the present invention.

FIG. **5** is a block diagram illustrating the vehicle body/powertrain control subsystem according to an embodiment of the present invention.

FIG. **6** is a block diagram illustrating the vehicle telematic subsystem according to an embodiment of the present invention.

FIG. **7** is an operational flowchart illustrating process steps performed by software functions in accordance with telematic and power functions in a vehicle system according to an embodiment of the present invention.

FIG. **8** is an architectural diagram illustrating a telematic sensor chip according to an embodiment of the present invention.

DETAILED DESCRIPTION

FIG. **1** shows a generalized embodiment of a vehicle (**100**) including main systems comprising a power system (**101**), an electrical system (**102**), a telematic system (**103**), and a body/powertrain control system (**104**) integrated within the vehicle (**100**). Different embodiments can include alternative vehicle configurations. For example, an embodiment may include the body/powertrain control system (**104**) deriving mechanical energy directly from the power system (**101**) via work done by the combustion engine, such as in a conventional automobile. A vehicle (**100**) is defined broadly to include automobiles, trucks, vans, motorcycles, tractor-trailers, haulers, ambulances, fire engines, police cars, taxis, buses, and similar fleet vehicles, heavy equipment machinery such as backhoes, forklifts, and bulldozers, and can include other devices that in or on which any person or thing may be carried and transported including boats, vessels, ships, carriers, barges, submarines, aircraft, helicopters, and space craft.

FIG. **2***a* shows power system (**102**), which preferably is source of energy for the traction motor (**204**). The fuel cell stack (**200**) as shown in FIG. **2***b* serves as the power source. The fuel cell stack (**200**) is an alternative to conventional combustion as primary source of power for the traction motor. A fuel cell stack (**200**), however, can be used in conjunction with a combustion engine and can serve as a secondary or auxiliary power source for the traction motor (**204**) or as a main power source for other components in the vehicle in want of electric energy. For example, the combustion engine may turn the traction motor (**204**) while the fuel cell stack (**200**) may power the components in the telematic system (**103**) and/or the body/powertrain control system (**104**) components. The fuel cell stack (**200**) is comprised of multiple Proton Exchange Membrane (PEM) fuel cells (**214**) using solid polymer electrolyte as shown in FIG. **2***c*. The number of fuel cells (**214**) in the fuel cell stack (**200**) determines the amount of electricity that the fuel cell stack (**200**) can provide to the vehicle (**100**), to the telematic system (**103**), and to the body/powertrain control system (**104**). A large number of fuel cells (**214**) in the fuel cell stack (**200**) produces more electricity than a fuel cell stack (**200**) with fewer fuel cells (**214**).

As shown representative fuel cell stack (**200**) shows expanded single fuel cell (**7**) including membrane electrode assembly and two flow field plates; this assembly uses flow field plate (**2**) such that hydrogen and air gases are supplied to the electrodes through channels formed in flow field plates. Hence hydrogen (**3**) flows through channels in the flow field plates to anode where platinum catalyst promotes separation into protons and electrons. Membrane electrode assembly (**4**) includes anode and cathode electrodes with thin layer of catalyst, bonded to either side of PEM fuel cell. Air (**5**) flows through channels in the flow field plates to the cathode, and oxygen in the air attracts hydrogen protons through PEM fuel cell. Also air stream removes water created as byproduct of electrochemical process. In a completed fuel cell stack (**6**), single fuel cells are combined into a fuel cell stack to produce desired level of electrical power.

PEM fuel cells (**214**) are included in fuel cell stack (**200**) in one embodiment of this invention. Alternatively, other types of fuel cells can be used in the fuel cell stack (**200**) instead of the PEM fuel cell (**214**). For example, a solid oxide fuel cell (SOFC) as shown in a porous zirconia and nickel tubular design in FIG. **2***d*, an alkaline electrolyte fuel cell as shown in FIG. **2***e*, a molten carbonate fuel cell as shown in FIG. **2***g*, or a phosphoric acid electrolyte fuel cell as shown in FIG. **2***f* can be used as substitute fuel cells in the fuel cell stack (**200**) in the power system (**101**) of the vehicle (**100**).

The fuel cell stack (**200**) creates electricity by combining air (O_2) and hydrogen (H_2). The O_2 is filtered through the vehicle (**100**) air intake system (**209**) and travels to the humidifier (**208**) and then to the fuel cell stack (**200**). The hydrogen fuel (H_2) is stored in the fuel storage tank (**211**). The fuel storage tank (**211**) feeds the H_2 through the fuel system (**210**) to the humidifier (**208**) and then to the fuel cell stack (**200**) where it combines with the O_2 and forms water (H_2O) which can be used for cooling components of the vehicle (**100**) system and/or is emitted as the vehicle (**100**) exhaust. Optionally, a fuel system (**210**) can include an on-board reformer when pure hydrogen is not available as fuel for the fuel cell stack (**200**). The reformer can derive the hydrogen from other forms of natural gas.

The fuel cell stack (**200**) generates electricity that is sent to the power control unit (**201**). The power control unit (**201**) controls precisely the distribution of electric power of the fuel cell stack (**200**) and the lithium-ion battery (**203**). The lithium-ion battery (**203**) assists the output of the fuel cell at ignition and during acceleration and stores the regenerative power, such as created from heat during braking. Optionally, the lithium-ion battery (**203**) can be used as a rechargeable device, receiving charge from braking or also from electricity generated directly from the fuel cell stack (**200**). The lithium-ion battery can also assist with electrical requirements demanded by applications in the telematic system (**103**) and in the body/powertrain control system (**104**). For example, a vehicle containing a 12-14-volt electrical system as opposed to a 42-volt electrical system may require additional electric power due to numerous add-on or post-sale telematic applications.

Electricity distributed from the power control unit (**201**) passes through the inverter (**202**) to the traction motor (**204**). The traction motor turns the wheels (**212**, **213**) of the vehicle. Alternatively, a sensor (**205**) in the traction motor (**204**) can detect the speed of the vehicle by measuring the rotations of the motor shaft turned by the traction motor (**204**). The sensor (**205**) in the embodiment of this invention can either be an optical sensor, a magnetic sensor, or an isolated optical sensor. For example, a slotted wheel on the motor shaft alternately blocks and unblocks the light path between the LED and the phototransistor in the slotted switch as the motor shaft rotates. Alternatively, a reflective optical sensor can be used for the same function.

The sensor (**205**) in the traction motor (**204**) may be susceptible to motor oil exposure, reducing the ability of the sensor to detect rotation because of excessive interrupts. Additional hardware or software (**302**) can be added to detect unusual conditions. For example, the software (**302**) can have a timer that tracks the time between the excessive interrupts detected by the reflective sensor (**205**). When the sensor interrupt service routine is exited and immediately reentered by the software (**302**), the interrupt service routine could disable the interrupt and set a flag to notify the system or the user of the error.

Different embodiments of the power system (**101**) can include alternative power configurations. For example, an internal combustion engine, as opposed to a fuel cell stack (**200**), may be used in the power system (**101**) as the driving force for the traction motor (**204**). In this case, the body/powertrain control system (**104**) is run primarily from mechanical energy directly from the power system (**101**) as opposed to electric energy from the electrical system (**102**) as currently shown in FIGS. **1** and **2***a*.

The power control unit (**201**) is also connected to the central controller (**206**), which is the core element of the vehicle (**100**), in that the power control unit (**201**) serves as the multimedia center for the user to control the power system (**101**), and the electrical system (**102**), the telematic system (**103**) and the body/powertrain control system (**104**) via the gateway (**207**). The main tasks of the central controller (**206**) are to control the user interaction with the power system (**101**), and the electrical system (**102**), the telematic system (**103**) and the body/powertrain control system (**104**), and serve as a front-end for the telematic applications in the vehicle (**100**).

FIG. **3** shows functional interaction between the central controller (**206**) and the gateway (**207**). FIG. **3** represents one configuration in which the central controller (**206**) and the gateway (**207**) interact. The central controller (**206**) accesses the power system (**101**), and the electrical system (**102**), the telematic system (**103**) and the body/powertrain control system (**104**) through the gateway (**206**). The gateway (**207**) is a programmable signal interconnect, router, or switch between the electrical system (**102**), the telematic system (**103**) and the body/powertrain control system (**104**) and integrates the vehicle multimedia interfaces discussed below. The central processing unit (CPU) (**300**) with associated processor runs the software (**302**) for the vehicle (**100**). RAM (**301**) stores the software functions for execution by the microprocessor (**304**) to enable informational alerts to the user and user response commands. For example, GPS navigation (**601**) information that guides the user along a specific route in a GPS map is stored in the RAM (**301**). The memory keeps track of the vehicle position on the map as the user guides the vehicle along the route. Optionally, the memory can store user input each time the vehicle turns onto a new street in the route.

Additionally, the memory in the RAM (**301**) stores user preferences in the vehicle (**100**) related to seat adjustment, steering wheel protrusion, and air conditioning or heater temperature. Additionally, the memory can be used to store security alerts, such as an open door, or disengaged seatbelt, and wait for user response as to a solution. RAM (**301**) can be installed as standard equipment, or alternatively can be replaced with add-on RAM if the user decides to install additional software to support extra telematic features and/or devices.

The central controller (**206**) connects to the gateway (**207**) via the host bus interface (**303**). One or more microprocessors (**304**) assist the gateway (**207**) in performing the software (**302**) functions required by the power system (**101**), and the electrical system (**102**), the telematic system (**103**) and the body/powertrain control system (**104**) as shown in FIG. **5**. Optical isolator sensors can be employed in the microprocessor (**304**) to pass signals between circuits. The software (**302**) can be included as standard equipment in the central controller (**206**), or alternatively, additional software can be used to upgrade the central controller (**206**) for add-on telematic features implemented by the user. The software can be programmable to allow a flexible telematic system (**103**) design as well as to program the system specific to user needs. Programmable software can provide upgradeable interfacing on a large or small scale within the interfacing buses or as a complete bus-interfacing unit. It can allow interfacing between various protocols used by different application-specific standard products.

Software (**302**) and associated databases may be installed or partitioned in one or more telematic appliances (**103**) or other network-accessible device, and executable locally or remotely by one or more controller (**206**) or other processor provided in telematic appliance (**1013**) or other network accessible device.

The gateway (**207**) can support a variety of interfaces and system buses to support alternative designs, improvements, and upgrades to vehicle systems. The gateway (**207**) integrates the multimedia interfaces such as the vehicle multimedia bus (**600**), the media-oriented system transport (MOST) (**611**), the intelligent transportation system data bus (IDB) (**612**), and the universal serial bus (USB) (**613**) as shown in FIG. **6**. The gateway (**207**) is also a router for additional systems and/or buses in a vehicle. The gateway (**207**) supports various interfaces so the system can communicate with buses used by different manufacturers. Different interfaces for specific bus systems can be chosen. For example, in emergency vehicles, the gateway (**207**) can integrate an on-board traffic light control system for more efficient travel during emergencies. The gateway (**207**) may also support additional computer-related communications or wireless interfaces such as Ethernet, WIFI, and Bluetooth.

FIG. **4** shows the electrical system (**102**). The electrical system (**102**) includes a 42-volt system that powers the telematic system (**103**), which requires approximately 36-volt loads (**401**), and the body/powertrain control system (**104**), which requires approximately 14-volt loads (**404**). These system loads can be redistributed in different ratios or quantities throughout the vehicle (**100**) systems in order to satisfy alternative electric load demands as a result of variations in vehicles and system configurations. For example, an ambulance or fire engine may contain a higher electric load requirement for its telematic devices than would a conventional automobile due to the greater number of such devices, such as medical or water pressure management equipment in these types of vehicles. Alternatively, a vehicle with few telematic devices may have a configuration comprised of the conventional 12-14-volt electrical system.

The 42-volt DC bus (**405**) supports the 36-volt battery charge/discharge unit (**400**). Similarly, a 14-volt DC bus (**406**) supports the 12-volt battery charge/discharge unit (**403**). A DC/DC converter (**402**) connects the 42-volt DC bus (**405**) and the 14-volt DC bus (**406**). In alternate electrical configurations, the electrical system (**102**) may include 12-14-volt system supporting the telematic system (**103**) and the body/powertrain control system (**104**). In such cases, the number of telematic and body/powertrain applications may be relatively low.

FIG. **5** shows the body/powertrain control system (**104**) branch of the vehicle (**100**). Software functions for the body/powertrain control system (**104**) are provided by the central controller (**206**) through the gateway (**207**) to the body/powertrain control bus (**500**). The body/powertrain control system (**104**) can support variations of buses depending on the specific requirements of the body/powertrain control system (**104**). For example, in the present embodiment of the invention, the body/powertrain control bus (**500**) supports body systems (**501**), powertrain (**502**), security systems (**503**), and gear control (**504**). Alternative body/powertrain control designs may contain more or less support branches. For instance, the vehicle security systems may be run by applications in the telematic system (**103**) instead of the body/powertrain control system (**104**), thus opening an available branch in the body/powertrain control system (**104**) for high pressure water pumps fire engines, or hydraulic lifts in heavy equipment machinery.

The body systems (**501**) include vehicle (**100**) components such as automatic door locks, power windows, interior lights, exterior lights, turn signals, windshield wipers, heater, electronic air conditioning, electronically heated seats, airbag deployment, and defrost mechanisms. The body systems (**501**) can have various applications depending on the type of vehicle to which they apply. For example, tractor-trailers can have alternative or modular body systems requirements due to a different functionality than a passenger vehicle.

The powertrain (**502**) branch allows user control with the transmission, the driveline, traction motor (**204**), throttle actuation, steering, active suspension and ride height adjustment. Optionally, the body/powertrain control system (**104**) can allow the user to control the transmission directly, such as for manual transmissions, depending on diver preference. Security systems (**503**) include applications including voice recognition, solid-state finger print scanners, theft alerts, and door lock sensors. The security system (**503**) can also alert the user of malfunctions within the vehicle (**100**) systems. For example, the security system can detect a failed LED in sensors that compromise vehicle safety or security. For instance, a comparator senses the voltage at the LED anode. When the LED is on, the voltage drop is approximately 1.2 volts, and the comparator output is high. If the LED opens, the voltage at the anode will rise to above 3 volts. In this instance, the LED is operating constantly. For switched LED that may occasionally be turned off, the voltage drop across the switching transistor is considered with the reference voltage, and the software (**302**) ignores the comparator output when the LED is turned off.

Although a disconnected LED is much more likely than a shorted LED, a second comparator may be added to detect the shorted condition. The reference voltage may be around 0.6V, and the software may declare an error if the voltage drops below the reference.

Gear control (**504**) allows for immediate shift from software driven automatic transmission to manual-on-demand transmission during vehicle operation at the request of the driver. Other gear control applications include equipment appendages on heavy-equipment fleet vehicles such as shovels, rollers, buckets, booms, ladders, hoes, and drills.

FIG. **6** shows the telematic system (**103**) branch of the vehicle (**100**). The central controller (**206**) communicates to the telematic system (**103**) at the vehicle multimedia bus (**600**), via the gateway (**207**) and the electrical system (**102**). Communication is enabled through media oriented system transport (MOST) (**611**). Optionally, communication can be made through intelligent transportation systems data bus (IDB) (**612**), universal serial bus (USB) (**613**), and Ethernet (**614**). The local interconnect network protocol from the central controller (**206**) can carry the communication to the telematic system (**103**), as well as between the between the power system (**101**), the electrical system (**102**), and the body/powertrain control system (**104**), by combining multiple sensors to satisfy the high data rate and enhance communication capability. These sensors, such as sensor (**205**), can be an optical sensor, a magnetic sensor, or an optical isolator sensor depending on the application; other sensors are described further herein. For example, optical sensors can be used to determine vehicle speed by measuring the rotations of the motor shaft. Magnetic sensors can be implemented in situations requiring user alerts that a door, or valve is open or shut. Optical isolator sensors can be employed in microprocessors (**304**) to pass signals between circuits.

The vehicle multimedia bus (**600**) feeds outgoing data to the human-machine interface (HMI) (**616**) and LCD terminals (**615**) for efficient display for the user. The human-machine interface (**616**) provides the mechanisms or devices that receive user input to respond to telematic responses, such as security alerts and navigational information. The mechanisms or devices can be additional LCD screens capable of touch screen command protocol. Optionally, the mechanisms or devices can be button interface wherein the user pushes buttons or turns knobs to input commands to the telematic system (**103**). The vehicle multimedia bus (**600**), the human-machine interface (HMI) (**616**), and LCD terminals (**615**) integrate together to provide the user access to all of the telematic system (**103**) components, including the CPU (**300**) in the central controller (**207**) for on-board computing, allowing for a synchronized system command and response between the user and the vehicle or machine. Additionally, the Ethernet can be used to enhance the communication between these devices and the user. One or more LCD terminals can be used depending upon user preference and the range of telematic equipment. The LCD terminals (**615**) can have touch screen displays allowing the user to interact with the telematic system (**103**) by pressing icons on an LCD screen. Additional outgoing data also can include audio messages to the user. The outgoing data can be customized regionally and updated over the life of the vehicle (**100**), thus supporting new telematic or electronic equipment that can be added on after vehicle (**100**) manufacture or purchase by the user. The vehicle multimedia bus (**600**) can interface with a range of telematic equipment that includes after-market equipment added on by the user.

Incoming data to the telematic system (**103**) includes Global Positioning System (GPS) navigation (**601**), additional telematic services (**602**), radio/TV (**603**) reception, phone (**604**), indoor wireless (**605**) system that can connect to user personal digital assistant (PDA) (**610**), AM/FM digital audio broadcast/digital multimedia broadcast (DAB/DMB) (**616**), satellite digital video broadcast (DVB) (**617**), and global system for mobile communication/universal mobile telecommunications system (GSM/UMTS) (**618**). Additional units in the telematic system (**103**) include radar sensors (**606**), camera systems (**607**), audio digital signal processing (DPS) system (**608**), and CD/DVD (**609**). The microprocessor (**304**) controls or provides all or many of the control functions of the telematic system (**103**).

The telematic system (**103**) combines wireless communication with GPS navigation (**601**) and embedded computing to deliver up-to-date information, onboard computing navigation, and security to the user. Through the GPS navigation (**601**), the user can receive through the LCD terminal (**615**) navigational, wheel-speed, and engine-speed information. The GPS navigation (**601**) can also provide the user with current traffic conditions, driving maps and directions, and speed and fuel efficiency data. In an emergency, this system can provide rescue services with the exact location of the vehicle.

Telematic services (**602**) include optional add-on systems available to the user depending on user preference. For example, in road-tolling regions, electronic road-tolling systems may exist that require compatible equipment and software programs on board user vehicles. These systems have the capacity to be updated by the user. Other applications include voice recognition mechanisms or other biometric identifiers that enable a set of preset conditions to be enabled automatically upon user identification. Examples include preset temperatures for the air conditioning or heater unit. Sensors (**205**) in the vehicle may sense external or internal ambient temperature and react to either heat or cool the vehicle (**100**) correspondingly.

Telematic services (**602**) may include adaptive network-accessible or electronically distributed services such that a vehicle telematic appliance or mobile user communicates or transacts with Internet, remote server, access point, or other nearby peer or service vehicle, for example, to detect or indicate automatically when electrical power usage is running high, telematic or power system failure or emergency condition, or energy reserves are low, such that additional vehicle or portable modular fuel cell supplies are accessed or delivered locally responsively or dynamically in the jurisdiction, location or area where the vehicle is traveling currently.

Optionally web-based wireless telematic services (**602**) may transmit and receive structured or unstructured tagged or untagged data and/or control document, instructions or signals with one or more telematic appliances (**103**) as coordinated programmably by controller (**206**) with such remote network nodes, for example, in a user personalized process such that telematic appliance (**103**) and fuel cell (**200**) loading or usage are correspondingly monitored, sensed, controlled or serviced adaptively locally or remotely.

The radio/TV (**603**) receives AM/FM DAB/DMB (**616**) from emitting sources in the area the vehicle (**100**) travels. Satellite DVB (**617**) allows local area television programming as well as digital cable television to be viewed on monitors within the vehicle. For example, a user can receive pay-per-view broadcasts from the vehicle (**100**).

The phone (**604**) is enabled by GSM/UMTS (**618**), which allows the user telephone to access to different countries from the vehicle (**100**). The phone (**604**) also allows for verbal communication between the user and remote operators capable of vehicle diagnostic tests, location information, safety information, and security information. Additionally, users can use the phone (**604**) as a convention cell or mobile phone.

Indoor wireless (**605**) uses the universal serial bus (USB) (**613**), Ethernet (**614**) or other computer interconnection, mesh, or grid interface to allow the user to connect to portable devices such as PDA (**610**) to synchronize, upload, or download files. Optionally, Bluetooth or other wireless radio interface, such as IEEE 802.11/15 (ultrawideband) protocol, can be used in place of or in combination with the Ethernet (**614**).

Radar sensors (**606**) work in conjunction with camera systems (**607**), wherein together both units utilize a storage unit (**619**) with a controller (**620**) and a memory (**621**) for storing data comprising vehicle-user situational awareness. Vehicle-user situational awareness includes lane departure warnings, blind-spot detection, pre-crash sensing, active cruise control, parking slot measurement, and radar parking and reversing aid.

Audio DSP system (**608**) can be used for voice-activated commands of telematic functions in the telematic system (**103**). This is an alternative to the touch screen on LCD terminals (**615**) or can be used in conjunction with the touch screen on LCD terminals (**615**). For example, the user can navigate a touch screen menu in which the icon functions also respond to voice activated commands via the audio DSP system (**608**).

On-board CD/DVD (**609**) can be connected to the vehicle media bus (**600**) via the USB (**613**), MOST (**611**), or IDB (**612**) interfaces. This system allows the user to listen to CDs or view DVDs or other format media on the vehicle entertainment units. The CD/DVD (**609**) can also provide access to the central controller's (**206**) CD-ROM player, where MP3 or other media format music files can be stored. MP3 music files can be sent to the vehicle (**100**) audio system for playback via the CD/DVD (**609**) interface.

FIG. **7** shows an operational flowchart for software functionality. Software (**302**) for theft avoidance branch of the security system (**503**) for the vehicle (**100**) is triggered when activated by the user during periods of vehicle non-operation. The software (**302**) detects open doors or ignition attempts by unauthorized users not possessing the vehicle key. The software (**302**) can recognize the user's vehicle key to be a conventional metal key, or alternatively the key can

be a remote control button from a hand-held key device assigned to the user. Optionally, the software (**302**) can recognize user codes on a keypad next to the door handle as well as a code on a keypad for the ignition. The software (**302**) saves the user the added expense of the conventional exterior alarm system and can save the user from higher insurance premiums. Deterring potential thieves also increases safety. When the software (**302**) recognizes the user's key, or the user's code on a keypad, the software automatically unlocks the vehicle door for user entry. The software (**302**) likewise enables the ignition when it recognizes the user's key, or the user's code on a keypad. If the software (**302**) does not recognize the key or code on the keypad, it triggers an alarm. The alarm can be audio, visual (such as flashing lights), or telephonic. The telephonic alarm alerts the user, police, or local operators having wireless communication to the vehicle via the telematic system (**103**). This communication can be via user, police, or operator cell phones or alternatively can be via the user's remote control handheld key device.

Both the alarm and the door unlock functions enabled by the software trigger sensors that activate the CPU (**300**) in the central controller (**206**). The sensors can be optical or magnetic sensors that sense if the vehicle doors have been opened or if they remain closed. The central controller (**206**) is in stand-by mode when the vehicle is not in use, but the security system is still active as initiated by the user. The CPU (**300**) in the central controller (**206**) activates the microprocessor (**304**) in the gateway (**207**) via the host bus interface (**303**). The microprocessor (**304**) runs additional software (**302**) that activates the power system (**101**), the electrical system (**102**), the telematic system (**103**), and the body/powertrain control system (**204**).

Software (**302**) in the power control unit (**201**) manages the distribution of electric power of the fuel cell stack (**200**) and the lithium-ion battery (**203**). For example, the software (**302**) determines if the fuel cell stack may need electricity from the lithium-ion battery (**203**) to assist with internal warm-up in the stack (**200**) before ignition. This increases performance by reducing the amount of start-up time required by the fuel cell stack (**200**) before ignition. Additionally, the software (**302**) distributes electricity from the lithium-ion battery (**203**) to assist the fuel cell stack (**200**) increase output during periods of acceleration. This increases vehicle (**100**) safety as well by assuring the vehicle (**100**) consistently maintains the required power for the traction motor (**204**) in mountainous or similar geographic terrain. The user saves cost by not having to purchase larger motors or larger fuel cell stacks to receive desired performance.

When the user activates ignition, the software (**302**) opens the fuel storage tank (**211**) and the air intake system (**209**) and channels the fuel through the fuel system (**210**) and oxygen through the air intake system to the fuel cell stack (**200**). The software (**302**) can determine the amount of fuel required for ignition and operation in selective terrains. For example, these can be either pre-set conditions programmed in the software (**302**) or the user can program the software (**302**) to feed more or less fuel to the fuel cell stack depending on the desired terrain, increasing vehicle performance and safety. The software (**302**) can also detect leaks in the either the fuel system (**210**), the air intake system (**209**), or the fuel storage tank (**211**) using optical and magnetic sensors, and alert the user on the LCD terminal (**615**). Optionally, an audio message can alert the user while in the vehicle (**100**). Alternatively, if leaks are detected by the sensors, the software (**302**) closes the fuel storage tank

(**211**) to stop fuel flow and command the vehicle to use electricity from the lithium-ion battery (**203**). This increases safety by reducing the amount of volatile fuel leaked to potentially hazardous locations in the vehicle (**100**). Safety is also increased by the lithium-ion battery (**203**) serving as an auxiliary source of power for the vehicle when it cannot rely on fuel for electricity.

In normal ignition conditions, the software (**302**) will manage the electro-chemical process in the fuel cell stack (**200**) and direct the electricity from the fuel cell stack (**200**) to the power control unit (**201**). From there the electricity is channeled through the inverter (**202**) and turns the traction motor (**204**). The software (**302**) can detect if sufficient electricity is traveling through the inverter (**202**) by way of optical and magnetic sensors. If the software (**302**) detects a lack of sufficient electricity, an alert can be sent to the user denoting such an error. The software (**302**) uses information collected from the sensor (**205**) in the traction motor (**204**) to provide the user with speed and tachometer information.

The software (**302**) activates the electrical system (**103**) which divides the electric loads into 36-volt loads (**401**) for the telematic system (**103**) and 14-volt loads (**404**) for the body/powertrain control system (**104**). The software (**302**) is able to manipulate this proportion if either the telematic system (**103**) or the body/powertrain control system (**104**) necessitate additional electric power. This increases system performance by providing immediate electric power to needy systems and reduces the cost of extra batteries to supply temporarily overburdened systems. Safety is preserved in this situation by providing user access and control to all telematic or body/powertrain functions in a consistent manner during vehicle operation.

The body branch and the powertrain branch of the body/powertrain system (**104**) can each have their own software (**302**) packages. The software uses optical or magnetic sensors for the body systems (**501**) to operate components such as automatic door locks. The door locks can be integrated as part of the vehicle security system as explained above. Power windows, interior lights, exterior lights, turn signals, windshield wipers, heater, electronic air conditioning, electronically heated seats, airbag deployment, and defrost mechanisms can also be enabled and controlled by software. For example, sensors in the vehicle (**100**) may detect a certain amount of moisture from raindrops and detect that windows or doors are left ajar after vehicle (**100**) operation. The software can either automatically close the windows or doors or provide the user with audio or visual alarms.

Similarly, if sensors in the vehicle (**100**) detect an absence of sunlight surrounding the vehicle, and the user failed manually to activate the headlights, the software can either automatically close the windows or doors or provide the user with audio or visual alarms. This would increase safety in instances when the user failed to turn on the headlights at dusk or at other times during the night. Optionally, solar cells in the vehicle (**100**) headlights could be used to detect the absence of sunlight as opposed to sensors.

The air conditioning and heater unit of the body system (**501**) can be pre-set by software parameters to engage upon a verbal command or other biometric identifiers in the vehicle. Sensors (**205**) in the vehicle may sense a certain external or internal ambient temperature and react to either heat or cool the vehicle (**100**) correspondingly.

Optionally, the wipers and defrost may be activated by the software if sensor detect moisture on the windshield or frost on the rear window. The software can be programmed with variations in parameters to be activated or deactivated according to climate or geography depending on vehicle location and use. These software functions increase vehicle performance and safety by compensating for careless users who do not activate these functions manually.

Software can supervise the powertrain (**502**) and gear control (**503**) branches of the body/powertrain control system (**104**) to allow the user to opt for on-the-fly or in-motion manual control of the transmission as opposed to automatic control by the vehicle or software. ABS software determines the terrain on which the vehicle is traveling and gages the antilock mechanism based upon preset conditions for variation in terrain and pavement condition. For example, the ABS would perform according to a certain set of conditions for wet pavements and according to a different set of conditions for dry pavements. Additional presets can include snowy or sandy surfaces. This increases safety and vehicle performance according to variations in whether, climate, or geography and reduces costs associated with a reduction accident damages.

Software (**302**) controlled cruise control works in conjunction with radar sensors (**606**) and camera systems (**607**) to provide the user with an active cruise control that detects the acceleration or deceleration of a traveling vehicle ahead of the user's vehicle (**100**). As the lead vehicle accelerates or decelerates, the software commands the user's vehicle to accelerate or decelerate with the same magnitude. This increases safety for the user by allowing a constant buffer between the user's vehicle and the lead vehicle. Additionally, software (**302**) can assist the user with vehicle operation in the same manner by provide the user with lane departure warnings, blind-spot detection, pre-crash sensing, and active cruise control, parking slot measurement, and radar parking and reversing aid.

Software (**302**) can control the local interconnect network protocol from the central controller (**206**) to the vehicle multimedia bus (**600**). Software (**302**) is used for driver verification as a prerequisite to full telematic activation. Optionally, ignition of the traction motor (**204**) can be prevented by the software (**302**) as a security device if the voice recognition software does not recognize a registered user.

Software (**302**) can manage the HMI (**616**) and LCD terminals (**615**) for efficient graphical user interface display for the user and provide the user control access to telematic components as well as the CPU (**300**) in the central controller (**207**). The LCD software enables the user to use screen technology. Optionally, the user may use the HMI for telematic control. HMI (**616**) may employ various biometric or biosensor/actuator devices to enhance or enable human machine interface. The software (**302**) can be customized depending on user preference based on a desired complexity level. Additionally, the software (**302**) can be updated over the life of the vehicle to support new telematic or electronic equipment that can be added on after manufacture.

Software (**302**) can run the GPS navigation (**601**), additional telematic services (**602**), radio/TV (**603**) reception, phone (**604**), indoor wireless (**605**) system that can connect to PDA (**610**), AM/FM digital audio broadcast/digital multimedia broadcast (**616**), satellite digital video broadcast (**617**), global system for mobile communication/universal mobile telecommunications system (**618**), radar sensors (**606**), camera systems (**607**), audio digital signal processing (DPS) system (**608**), and CD/DVD (**609**), or each can maintain its own software.

Software combines with wireless communication to run GPS navigation (**601**) in order to deliver up-to-date information, onboard computing navigation, and security to the user. GPS navigation (**601**) software allows the user to receive through the LCD terminal (**615**) navigational, wheel-speed, and engine-speed information. The software can also provide the user with current traffic conditions, driving maps and directions, and speed and fuel efficiency data. Additionally, the software can provide rescue services with the exact location of the vehicle in emergency situations.

Software enables optional or add-on telematic services (**602**) electronic road-tolling systems that recognize individual vehicles, and charges the toll to the vehicle account. Software enables the user to keep track of the electronic account and pay online from inside the vehicle. Other applications include voice recognition software or other biometric identifier software that enables the user to define a set of preset conditions within the vehicle that conform to user standards upon recognition. Examples include preset temperatures for the air conditioning or heater unit, seat height and steering wheel protrusion, and an automatic or manual transmission.

The radio/TV (**603**) software manages AM/FM DAB/DMB (**616**) and satellite DVB (**617**) received from emitting sources in the area and allows the user to select channels via verbal commands or touch screen selection on the LCD terminals (**615**).

The phone (**604**) software manages mobile telecommunications information and distinguishes for the user personal telephone calls from emergency or diagnostic calls from remote operators.

Indoor wireless (**605**) software allows the user to use the connect to portable devices such as PDA (**610**) or laptops to synchronize, upload, or download files. The software can be compatible with Bluetooth interface.

Audio DSP system (**608**) software enables the user to create and use voice-activated commands of telematic functions in the telematic system (**103**). This software can be used in conjunction with the touch screen software on LCD terminals (**615**). For example, the software can allow the user to navigate a touch screen menu in which the icon functions and respond to voice activated commands at the same time.

On-board CD/DVD (**609**) software allows the user to burn or listen to CDs or view DVDs on the vehicle entertainment units. The CD/DVD (**609**) software can also provide access to the central controller's (**206**) CD-ROM player, where MP3 music files can be stored. The software allows MP3 music files to be sent to the vehicle (**100**) audio system for playback via the CD/DVD (**609**) interface.

Optical, electric, and electromagnetic links within the power system (**101**), an electrical system (**102**), a telematic system (**103**), and a body/powertrain control system (**104**) may be redundant. This is made possible through redundant sensor configuration throughout the system.

For example, a failed LED in a sensor (**205**) can cause the system to operate in an unsafe manner. For instance, a safety lid that remains open during machine operation. A remedy for failed LED in the sensor (**205**) includes two sensors for the lid, one that's blocked when the lid is open and one that's blocked when the lid is closed. For operational functionality, both sensors (**205**) must be in the correct (lid closed) position.

Sensors (**205**), including optical sensors, magnetic sensors, and optical isolator sensors can be placed in devices and mechanisms in vehicle (**100**) systems as mentioned above. Sensors in the power control unit (**201**), the fuel cell stack (**200**), the central controller (**206**), the gateway (**207**), security systems (**503**), gear control (**504**), GPS navigation (**601**), telematic systems (**602**) units, storage unit (**619**), and indoor wireless (**605**) can have chips in them that aid software (**302**) functions.

FIG. **8** represents a telematic sensor chip (**800**) comprising a micro-electro-mechanical-system (**801**) in a biometric sensor (**802**). The micro-electro-mechanical-system (**801**) enables the biometric sensor (**802**) to detect and match vibrations from the user's voice to determine user identity. The biometric sensor (**802**) sends a command to the telematic biometric devices (**803**) that either allows or disallows the user access to activate and control devices in the telematic system (**103**) depending on user identity verification.

Additionally, the micro-electro-mechanical-system (**801**) enables the biometric sensor (**802**) to detect and match fingerprints or thumb prints from the user's hand to determine user identity. The biometric sensor (**802**) sends a command to the telematic biometric devices (**803**) that either allows or disallows the user access to activate and control devices in the telematic system (**103**) depending on user identity verification.

Additionally, the micro-electro-mechanical-system (**801**) enables the biometric sensor (**802**) to detect and match retinal scan of the user's eyes to determine user identity. The biometric sensor (**802**) sends a command to the telematic biometric devices (**803**) that either allows or disallows the user access to activate and control devices in the telematic system (**103**) depending on user identity verification.

Micro-electro-mechanical-system (**801**) or biometric device (**802**) may include, couple to, or be provided with single or multiple array of discrete or integrated structures including surface acoustic wave interdigitated transducer or sensor, microactuator, microaligner, accelerometer, transducer, microgyroscopes, cantilever beam or micromanipulator, thin membrane, rotor or microgear, micromotor, micronozzle, microgripper, microphone, microbridge, microresonator, micropump, microarray or biogenetic sensor, pressure/strain gauge, micronose or gas sensor, torsion mirror, thermopile, and/or microsensor using material such as silicon, polysilicon, germanium, carbon, gallium arsenide, quartz, silicon carbide, silicon nitride, alumina, sapphire, or silicon dioxide.

For example, microsensor may detect, sense or measure mechanical measurands, such as vehicle, user, or telematic appliance acceleration or velocity using microbridge or microresonator, acoustic energy or sound level using microphone, altitude or position displacement using capacitor or global positioning satellite receiver, roll or yaw using microgyroscope or accelerometer, pressure or temperature, shock or vibration, or force or torque using microcantilever.

Generally vehicle telematic system (**103**) and automated software control process electronically integrates power system (**101**) using controller (**206**), fuel cell stack or module (**200**), and one or more telematic appliances (**103**). Such telematic or control functions may be implemented in one or more digital or analog local or remote software, firmware, hardware, reconfigurable logic, or simulation models, or partitioned or redundant fixed or programmable combination thereof.

Preferably controller (**206**) couples electrical power from fuel cells (**200**) adaptively to selected telematic appliance (**103**). As understood and defined herein term "adaptive" or "adaptively" is interpreted broadly and understood generally to mean or refer to operational capability including one or any function that responds, adjusts, aligns, or corrects reactively to environmental, context, control or data signal, pattern, or other stimuli or feedback, or predicts or extrapolates proactively according to prior or current environmental, context, control or data signal, pattern or other stimuli or feedback, for example, to mimic, self-learn, compensate, repair, diagnose, adjust, change, compensate, tailor, or otherwise structurally or functionally modify.

Optionally controller (**206**) causes electrical power from fuel cell module (**200**) to be stored in lithium-ion or other rechargeable battery or energy storage. Fuel cell components may be coupled or packaged in modular assembly for easy access and connection either embedded to vehicle or portable for motile handling with certain detachable telematic appliances.

Optionally controller (**206**) configures fuel cell module (**200**) to generate 42-volt, 14-volt, or other voltage electrical power, as may be used by one or more telematic appliance (**103**).

Optionally controller (**206**) couples to fuel cell module (**200**) or telematic appliance (**103**) through shared connection or other electrical interconnect, wire, bus or channel, through which synchronous or asynchronous control signal and/or power signals are provided or transmitted simultaneously or at separate times.

Optionally controller (**206**) couples electrical power from a generator, solar cell, or other electrical power generation source as backup auxiliary to one or more telematic appliance (**103**).

Optionally controller (**206**) controls electrical power in response to a sensor signal provided by telematic appliance (**103**). Sensor signal may represent fault or error condition, media format or load, or location or jurisdiction of telematic appliance (**103**).

Optionally controller (**206**) adaptively controls electrical power reactively in response to measured quality of electrical power signal, proactively according to predicted function or scheduled service in telematic appliance (**103**).

Foregoing descriptions of specific embodiments of the invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Modifications and variations are possible in light of the above teaching. For example, applicant contemplates that present invention may be applied for various purposes, such as economizing use and optimizing storage of fossil fuels or other non-fossil energy conservation, as well as bioinformatic/biohazard or other remote sensor application for homeland security and defense or anti-terrorist surveillance or control functions.

The embodiments were chosen and described in order to explain the principles and the application of the invention, thereby enabling others skilled in the art to utilize the invention in its various embodiments and modifications according to the particular purpose contemplated. The scope of the invention is intended to be defined by the claims appended hereto and their equivalents.

The invention claimed is:

1. An apparatus comprising:

a primary power source for driving the motor;

an auxiliary power source for supplying electrical energy to on-board components;

a telematic appliance; and

an electronic controller for managing the power distributed between the auxiliary power source and the primary power source; wherein the electronic controller adaptively couples electrical power from the auxiliary power source to the telematic appliance.

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(12) INTER PARTES REEXAMINATION CERTIFICATE (1326th)

United States Patent

Fernandez

(10) Number: US 7,374,003 C1
(45) Certificate Issued: Aug. 12, 2016

(54) **TELEMATIC METHOD AND APPARATUS WITH INTEGRATED POWER SOURCE**

(76) Inventor: **Dennis S. Fernandez**, Atherton, CA (US)

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(51) **Int. Cl.**

B60L 1/00	(2006.01)
B60L 11/18	(2006.01)
B60L 15/20	(2006.01)

(52) **U.S. Cl.**
CPC ***B60L 11/1881*** (2013.01); ***B60L 1/00*** (2013.01); ***B60L 11/1892*** (2013.01); ***B60L 11/1894*** (2013.01); ***B60L 15/2045*** (2013.01); *B60L 2240/622* (2013.01); *B60L 2250/10* (2013.01); *B60L 2250/30* (2013.01); *Y02T 10/645* (2013.01); *Y02T 10/72* (2013.01); *Y02T 10/7283* (2013.01); *Y02T 10/7291* (2013.01); *Y02T 90/16* (2013.01); *Y02T 90/161* (2013.01); *Y02T 90/162* (2013.01); *Y02T 90/34* (2013.01); *Y10S 903/944* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

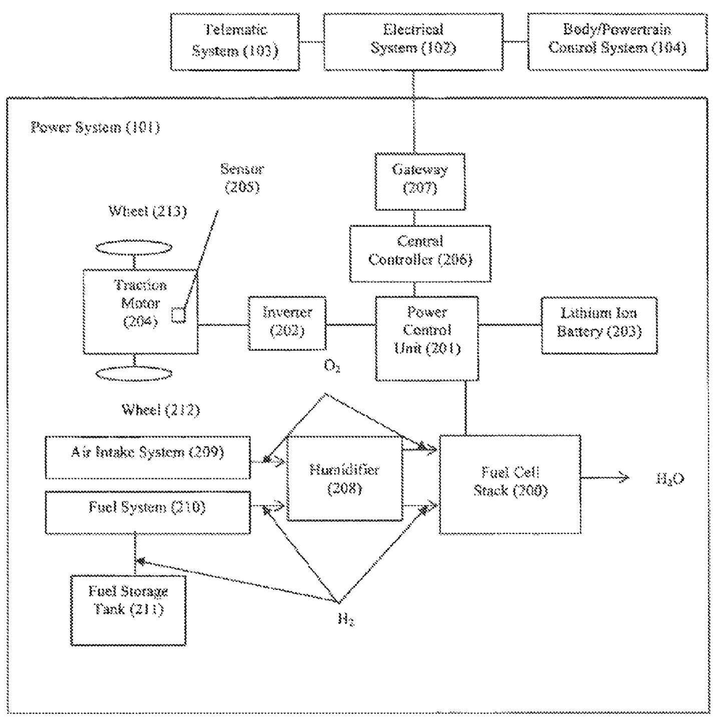
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 95/002,257, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Anjan Deb

(57) **ABSTRACT**

Telematic method and apparatus adaptively uses fuel cell power source in vehicle with integrated power system, electrical system, telematic system, and body/powertrain system. Telematic communications systems including internet, digital video broadcast entertainment, digital audio broadcast, digital multimedia broadcast, global positioning system navigation, safety services, intelligent transportation systems, and/or universal mobile telecommunications system. Network-accessible software enables integrated modular function for automated control and provision of fuel cell resources for telematic appliance and/or other vehicle electro-mechanical devices.



INTER PARTES REEXAMINATION CERTIFICATE

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claim **1** is cancelled.

* * * * *

Appendix FERDOWSI01

Plug-in Hybrid Vehicles - A Vision for the Future

Mehdi Ferdowsi, *Member, IEEE*
Power Electronics and Motor Drives Laboratory
University of Missouri-Rolla; Rolla, MO 65409; USA
Phone: (573) 341-4552; Email: ferdowsi@umr.edu

***Abstract* – One of the unique advantages of plug-in hybrid vehicles is their capability to integrate the transportation and electric power generation sectors in order to improve the efficiency, fuel economy, and reliability of both systems. This goal is performed via integration of the onboard energy storage units of plug-in vehicles with the power grid by power electronic converters and communication systems. Employing energy storage systems improves the efficiency and reliability of the electric power generation, transmission, and distribution. Similarly, combining an energy storage system with the power train of a conventional vehicle results in a hybrid vehicle with higher fuel efficiency. In both cases, the energy storage system is used to provide load leveling. In this paper, viability of utilizing the same energy storage unit for both transportation and power system applications is discussed. Furthermore, future trends in analysis, design, and evaluation of distributed energy storage system for the power grid using power-electronic-intensive interface are identified.**

Index Terms - Infrastructures; Plug-in Hybrid Vehicles; Power Electronics.

I. INTRODUCTION

Transportation and electric power generation are the two major consumers of fuel. Constantly increasing price of fuel and global warming are the major motives to improve the efficiency and fuel economy of the vehicle fleet as well as the electric power generation [1-4]. Furthermore, with heavier power transfers, power systems are increasingly vulnerable to cascading failures. The power grid of the future needs to be more reliable and secure [5]. Integration of the vehicle fleet with the power grid has not been effectively investigated. Plug-in hybrids and vehicle to grid concepts [6] have been independently introduced; however, minimum effort has been done to systematically combine these two concepts and if none, there have been minor efforts on the identification of the required cyberinfrastructure of the future vehicle to grid concept.

I(A). Electric Drive Vehicles (EDVs)

An electric drive vehicle (EDV) is a vehicle in which partial or entire propulsion power is electrically provided. With this broad definition, EDVs include battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), fuel cell electric vehicles (FCEVs), plug-in hybrid electric vehicles (PHEV), and photo voltaic electric vehicles (PVEVs). What is common among all the EDVs is that they all have an energy storage unit (ESU) included in their power train. The ESU may consist of batteries, ultracapacitors, flywheels, or a combination of at least two of them. Interaction of the ESU with the power train improves the overall efficiency of the system.

For instance, in an HEV, efficiency improvement is attained by running the main source of power, internal combustion engine (ICE), at a constant operating point or at least with minimal operating point variations. This gives the opportunity to the designers to optimize the efficiency and performance of the ICE at that constant or relatively constant operating point. Road load demand, on the other side, is not constant. In order to generate enough power, the operating point of the main source of power has to bet set equal with the average road load demand. If vehicle's power demand is more than what the main source of power generates, then the extra required power is supplied by the ESU. If vehicle's power demand is less than what the ICE generates, then the extra generated power is stored in the ESU as depicted in Fig. 1.

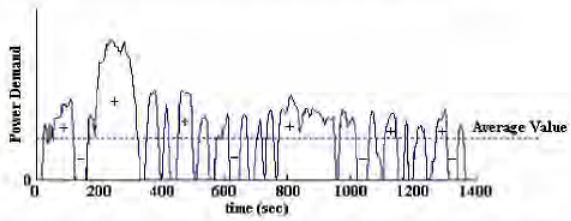


Fig. 1. Instantaneous and average power demand in a typical drive cycle.

So, the idea is to generate power at a relatively constant level, if more power is required discharge the ESU and if less power is required charge the ESU. Overall efficiency of the system improves due to the constant operating point of the ICE or fuel cell (FC). Although designed based on this concept, in real hybrid vehicles, the operating point of the ICE is not absolutely constant, hence the overall efficiency of the system is not as high as that of an ideal hybrid. The major practical constraint is that the instantaneous mechanical load demand of the vehicle is not predictable and highly depends on the vehicle type, city or highway driving cycles, and driver's driving habits. Therefore, the major challenge in improving the efficiency of hybrid vehicles is to predict the load demand and design the power management strategy as well as the capacity of the ESU storage unit based on the predicted road load.

I(B). Power Grid

The demand for electricity is not constant over a 24-hour cycle. Fig. 2 depicts a typical daily 24-hour load profile [7]. More interestingly, the price of power generation is not

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constant and varies from the base load power rate of 5 ¢/kWh to the daytime rates such as 30 ¢/kWh. By using an ESU, the exact same concept of power train hybridization of vehicles is applicable [8]. Excess generating capacity available during periods of low demand can be used to store energy in the ESU. The stored energy can then be used to provide electricity during periods of high demand, helping to reduce power system loads during these times [9]. Furthermore, many renewable resources, wind and solar power, for example, are intermittent, i.e., they are not available steadily [10-12]. Storing energy from the renewable source allows the supply to more closely match the demand. Energy storage can improve the quality, efficiency, reliability, cost-effectiveness, and flexibility of the electric utility system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient base load generation, and allowing greater use of renewable energy sources [13]. In addition, they also reduce the environmental impact of electricity generation, transmission, and distribution [14]. Conventionally, ESUs connected to the power grid have been implemented in small and medium scales including batteries, compressed air energy storages, flywheels, pumped hydro, ultracapacitors, and superconducting magnetic energy storages [15].

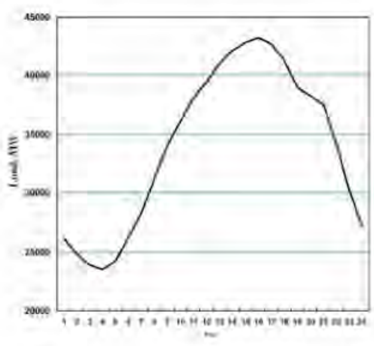

Fig. 2. A typical daily 24-hour load profile.

I(C). Integration of the Vehicle Fleet with the Power Grid

In the last two subsections, it was discussed how the application of an ESU benefits the performance, efficiency, cost, and reliability of both vehicles and power systems. Utilization of ESUs in vehicles is already available on the market as hybrid vehicles. ESUs with higher capacity will soon be available on the plug-in hybrids. On the other hand, ESUs in various capacities and with various mechanisms are already connected to the grid. One might devise methods to use the same ESU for both purposes [16]. It is obvious that the capacity of the ESU of a single vehicle is not comparable to the required ESU for the power grid; however, considering 150 million vehicles in the US, the idea of integration may not be too unrealistic. Considering the projected data, by the year 2020, at least ten percent (%10) of the vehicle fleet will be in some form of EDVs with a storage capacity of at least 30 kWh. The storage capacity of the whole EDV fleet will be 450 GWh; whereas the power capacity of the total installed generation capacity of the U.S. electric utilities is almost 750 GW [17]. The future envisioned for the power systems includes millions of EDVs plugged in to the power grid. Vehicles are in use almost an average of 1 hour per day so they idle for 23 hours a day. This indicates that having EDVs plugged into the grid does not impose any restrictions on the driving schedule of the drivers [18].

Benefits to the drivers – buying energy at nights and selling it back during the peak load demand will be lucrative or at least drivers can enjoy using a free battery pack [19]. In addition, drivers will be relying on the electric energy purchased off the grid as the major source of traction in their vehicles (the concept of plug-in hybrids) [20, 21]. This in turn improves the market penetration of EDVs. Furthermore, the equivalent gas mileage of the vehicles will drastically increase.

Benefits to the power grid – EDVs connected to the grid provide a range of services to the power network including backup power for homes and business, peak shaving, regulation, reactive power, and transmission stabilization [22]. Another major advantage is that unlike the utility-owned energy storages, EDVs are geographically distributed and sit closer to loads [23]. This leads to less stress on the power transmission lines. Furthermore, ESUs in the future vehicles offer advantages in modularity, speed of response, and efficiency [24].

Benefits to the environment – The idea of plug-in EDVs increases the penetration of more green vehicles to the market and also improves the efficiency of the electricity generation [25-27]. As a result of that both transportation and electric power generation sectors will be environmentally friendlier.

Benefits to the government – Transportation and electricity generation are the two major consumers of fuel. Having these two sectors interleaved by a distributed ESU, strategic planning for the energy market will be easier and more fruitful.

II. Application Considerations

It is important to consider the expectations, limitations, priorities, and requirements of both drivers and the power grid as they share the same ESU.

Considerations on the driver side - 1) Ability to start charging the ESU of the vehicle at any desired time. 2) Ability to stop the charging process at any desired time. 3) Ability to charge the ESU as quickly as possible so that the vehicle is ready for the next trip in the shortest time. 4) The size and weight of the ESU should be optimized. 5) The ESU should easily be exchangeable so that each driver is able to select the ESU with the right storage capacity based on his/her daily driving routine. 6) In order to optimize the fuel consumption, intelligent power management of the vehicle is desirable. 7) State of charge of the ESU needs to be determinable in an accurate way. 8) The vehicle should be able to communicate with the energy management center to report its location and state of charge of its onboard ESU.

Considerations on the power grid side - Power grid has two types of interaction with the vehicles. i) As an energy source for traction purposes. Nevertheless, vehicles consume parts of the energy stored in the ESU by the power grid and behave as a load to the power grid. ii) As a distributed ESU while the vehicles are not in use and plugged to the network. Some considerations for the power grid can be summarized as 1) Ability to charge the ESU at any desired time and at any desired pattern. 2) Ability to stop charging the ESU at any desired time no matter what to state of charge of the ESU of the vehicle is. 3) Since some of the energy stored in the ESU will be used for traction purposes, the net power flow will be from the power grid to the ESU of the vehicles. The power grid would like to have absolute control over the time periods and charging profile of positive and negative net power flows. 4) It is desired to know the position of the vehicle and predict the next place at which the vehicle will be plugged in. 5) It is desired to be aware of the state of charge of the ESU of the vehicles at all times and predict their future power demand. 6) The power that vehicles receive or return needs to have a high power factor. 7) The ESU of vehicles should not be fully charged as there might always be some empty capacity required.

III. A Vision for the Future and Enabling Technologies

The driver unplugs the vehicle and drives to work. Prior to that, while the vehicle is still plugged, the state of charge of the ESU has been optimized based on the previous driving patterns of the driver, the time of the day at which he/she starts using the vehicle, and the forecasted daily power demand of the grid. If the driver uses the vehicle for a short range (case a –purely electric configuration) then the vehicle will only consume the energy stored in the onboard ESU. If the driver uses the vehicle for a long range (case b – hybrid configuration) the onboard source of power in vehicle, i.e. ICE or fuel cell, will be turned on and provides parts of the vehicle's road load. In case a, energy management center is being updated about the state of charge of the vehicle's onboard ESU every couple of minutes as well as the location of the vehicle via wireless communications. Grid operators require this information to forecast the required charge that the vehicle demands the next time that it is connected to the grid. In case b, the onboard intelligent power management unit predicts the distance to be driven and manages the power split between the ICE (or fuel cell) and ESU. The power management communicates with the energy management center to report the estimate of the state of charge of ESU at the end of the trip and also updates itself based on instantaneous and future power grid load forecast. The intelligent power management unit uses this information to make decisions upon the amount of stored energy that can be released for traction. The next location at which the vehicle will be plugged in also will be estimated and reported. After the trip is over and the vehicle has reached the destination, the driver will plug in the vehicle back to the grid. This would likely be at the parking lot at which the driver works or the shopping mall. Depending on case a or b the state of charge of the ESU might be lower than its initial value at the time when the trip started. Now the energy management center needs to predict how long the vehicle will be plugged in. This will be based on the history of the schedule of the driver. The objective is to charge the ESU to the level that is required for the next trip of the driver as well as using the ESU for power system purposes (regulation, reactive power, peak power shaving etc.). The pattern at which the vehicle is being charged depends on the current and future load demand and regulation strategies. Maybe the vehicle will not be charged if the state of charge is high enough for the predicted next trip. It also depends on the initial and required final state of charge of the ESU during the grid connection. After a while, the driver starts it second trip and the same things that needed to be done on the first trip will be repeated. The difference is that this might be the trip back home and probably the last trip of the driver in the day. Hence the boundary conditions for the onboard power management unit and the energy management center are different. After this trip is finished the vehicle is plugged back into the grid (most probably at home). The possibility of the third trip will be calculated. If the chance of the third trip is low, the power grid has plenty of time over night to recharge the ESU at a proper time and using the desired pattern. If the third trip is highly probable, then the same things that were done over the first stopping time need to be done.

Enabling technologies and the future of ESU integration of the grid and the vehicle fleet include 1) bi-directional charging unit with high power factor (on board or off board), 2) bi-directional meters (onboard or off board) [28], 3) communication between the vehicle and the energy management center, 4) GPS system, 5) cyberinfrastructure, 6) intelligent on-board power management unit, 7) intelligent energy management center, and 8) energy storage unit. Fig. 3 depicts the proposed system. Although wireless communication is used for illustration in Fig. 3; however, the Internet could be used as well.

IV. Future Research Trends

IV(A). Power Train

Power train configuration of hybrid vehicles, i.e. series, parallel, and series-parallel, is designed in a way that energy conversion losses from the energy sources to the wheels are minimized [29]. Major difference of conventional hybrids and plug-in hybrids is that the vehicle is mostly driven by the electric energy source, especially on urban driving cycles. Furthermore, charging and discharging mechanism of the ESU is different than that of conventional hybrids and is not limited to the interactions of the ESU with the traction motor/generator set and the generator driven by the ICE [30]. These differences demand for an investigation in potential modifications in the hybrid power trains to make them more suitable for plug-in applications.

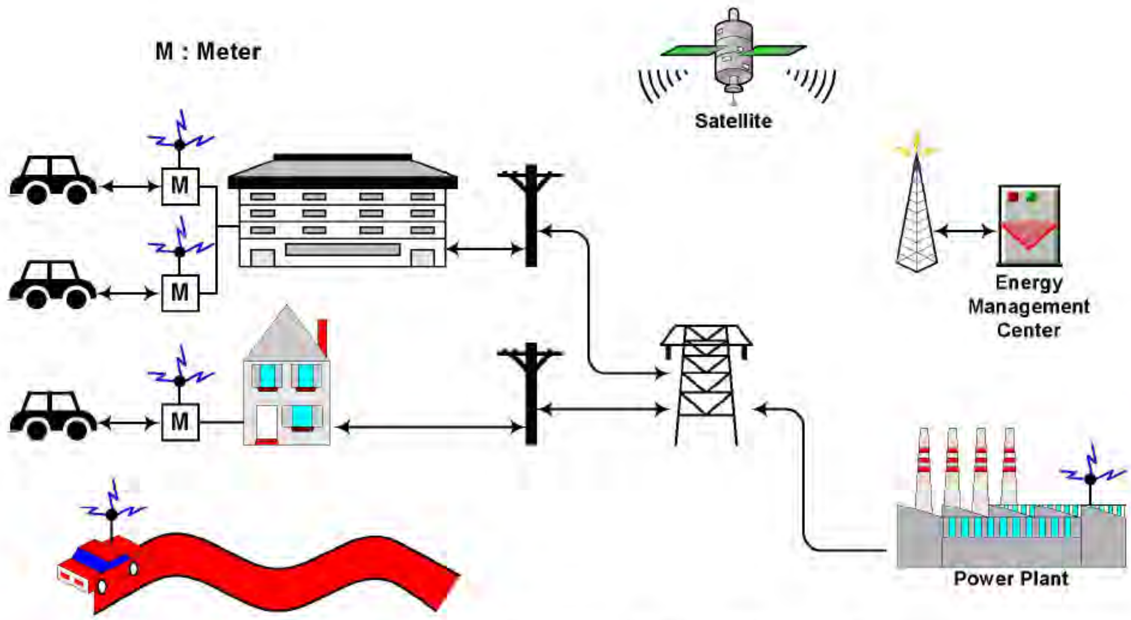

Fig. 3. Illustrative schematic of the integration of vehicles with the power grid.

IV(B). Energy Storage Unit (ESU)

ESU is conventionally comprised of a battery unit [31]. Despite enormous improvements in battery technology, the major limiting factor of HEVs is batteries due to their poor charge/discharge efficiency, short life cycles, and low current capabilities [32]. To alleviate these intrinsic limiting factors of batteries, application of alternative energy storage units including ultracapacitors and flywheels need to be investigated. As an alternative energy storage technology, the advantages of ultracapacitors over batteries include long life cycles, high charge/discharge efficiency, high specific power, and wide range of operating temperatures (see Table I) [33, 34]. The two notable drawbacks of ultracapacitors are low specific energy and wide voltage variations as energy is taken out of or put into the device.

Even though purely ultracapacitor HEVs have been commercialized (Honda FCX), an ESU comprising both batteries and ultracapacitor seem to be the promising choice for the future HEVs. The basic idea is to realize advantages of both batteries and ultracapacitors while keeping the weight of the entire ESU minimized through an appropriate matching [35, 36].

This combined ESU brings along some new challenges for the designers. The major questions to be answered are, knowing the characteristics of ultracapacitors and batteries, "what is the best capacity ratio for each one of them?" "What is the best method of combining them?" And "where is the most effective and efficient place to put them in the power distribution structure of HEVs?" Different structures have been introduced in the literature [37]; however, more research needs to be done.

TABLE I
COMPARISON BETWEEN BATTERIES AND ULTRACAPACITORS

	Lead-acid battery	Ultracapacitor
Charge time	1-5 h	0.3-30 s
Discharge time	0.3-3 h	0.3-30 s
Specific energy (W-h/Kg)	10-100	1-10
Specific power (W/Kg)	<1,000	<10,000
Cycle life	1,000	>500,000
Charge/discharge efficiency	0.7-0.85	0.85-0.98

IV(C). Charge Equalization

The ESU employs large series strings of battery and/or ultracapacitor cells to attain required high voltage level. As the ESU is charged and discharged as a unit, individual cell temperature and internal chemistry characteristics can cause capacity imbalances in the form of voltage variations. Imbalanced cell voltages are caused by differences in cell capacities, internal resistance, degradation, and ambient temperature during charging and discharging. Any capacity imbalance between the modules can threaten the long-term stability of the string as overall pack capacity is brought to the upper and lower limits of charge. Imbalanced cell voltages can cause cell overcharging and discharging, and decrease the total storage capacity and lifetime of the ESU [38, 39].

In order to equalize the charge of battery and/or ultracapacitor cells more efficiently in the ESU, new charge equalization techniques should be investigated [40, 41].

IV(D). Integration of Traction Motor Drive and Battery AC Charger

The power train of a plug-in hybrid vehicle consists of a three-phase traction motor drive and a single- or three-phase bidirectional battery charger [42]. The structure of these two converters is very much similar to each other, except for the power ratings. It will be of great advantage of integrating these two converters into one converter to save weight and production cost [43, 44]. The ac charger also needs to have an embedded system which stores the vehicle identification number (VIN) and includes a programmable unit, which is aware of the capacity of the ESU, a controller unit which enforces the charging pattern, and communication tools to transfer data to/from the meter.

IV(E). Onboard Power Management Unit

The required building blocks of the power management unit can be summarized as 1) communication block, 2) prediction block, 3) measuring block, and 4) central control block. Functionality of each one of these blocks will be described in the following paragraphs.

IV(E-1). Communication Block

This block includes both location communication system which is basically carried out by GPS (global positioning system) and data communication system which can be done via wireless implementation. Vehicles are expected to report their state of charge when they are unplugged from the grid to the grid operator. Also while plugged to the grid, the VIN of the vehicle, IP address of the meter, and charging or discharging patterns should be transmitted via either wireless communications or through the Internet.

IV(E-2). Prediction Block

This block is mainly in charge of estimation of the final state of charge of the ESU, while vehicle is being driven. The state of charge depends on the driving style, driving route and length, and traffic conditions. This can be accomplished by considering the speed profile, traffic situation [45], and built in GPS information.

IV(E-3). Measuring Block

The function of this block is to measure the state of charge of the ESU. There are several battery monitoring techniques introduced in the literature [46, 47] including midpoint voltage method, midpoint voltage monitoring during discharge, conductance monitoring, and discharge test.

IV(E-4). Central Control Block

Using a fuzzy control approach, the intelligent power controller can be designed as a fuzzy engine which makes a decision upon the amount of instantaneous power to be generated by the ICE. Some of the linguistic rules for this controller could be described as:

- If the congestion is low, then charge the battery during coasting by the power generated by the ICE.
- If the congestion is high, then discharge the battery during acceleration to help the ICE.

IV(F). Cyberinfrastructure

Cyberinfrastructure is expanded in modular increments [48]. It is being built and adopted quite rapidly, and once it is built, it will be much harder to alter or improve its foundations [49, 50]. Therefore, it is of grave importance to have broad scholarly participation in its construction [51-53]. In parallel with cyberinfrastructure development, knowledge gained through plug-in hybrid design has to be used to better define the new components required for the evolving cyberinfrastructure. As a high-impact application of cyberinfrastructure, the objectives should include identification of the required building blocks, tools, and technologies for future cyberinfrastructure development [54].

As depicted in Fig. 3, the required cyberinfrastructure consists of 1) onboard power management units embedded in the vehicles, 2) embedded systems in the meters, 3) communication tools, 4) central, or distributed, data processing units, and 5) grid energy management centers [55].

Each vehicle will have an onboard embedded system which intelligently manages power generation and storage dynamics. These embedded systems need to be interacting with the energy management centers via a large system of wireless communications or the Internet. Required information that has to be transmitted from the vehicles includes the state of charge of the energy storage unit, location of the vehicle, and estimation of driving duration.

V. Conclusions

Plug-in hybrid electric vehicles integrate transportation, power systems, and communications infrastructure. Future research trends in this growing field are identified and introduced in the paper.

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Appendix FERDOWSI02

Plug-in Hybrid Vehicles - A Vision for the Future

Publisher: IEEE

Mehdi Ferdowsi **All Authors**

Abstract

Abstract:
One of the unique advantages of plug-in hybrid vehicles is their capability to integrate the transportation and electric power generation sectors in order to improve the ... **View more**

Metadata

Abstract:
One of the unique advantages of plug-in hybrid vehicles is their capability to integrate the transportation and electric power generation sectors in order to improve the efficiency, fuel economy, and reliability of both systems. This goal is performed via integration of the onboard energy storage units of plug-in vehicles with the power grid by power electronic converters and communication systems. Employing energy storage systems improves the efficiency and reliability of the electric power generation, transmission, and distribution. Similarly, combining an energy storage system with the power train of a conventional vehicle results in a hybrid vehicle with higher fuel efficiency. In both cases, the energy storage system is used to provide load leveling. In this paper, viability of utilizing the same energy storage unit for both transportation and power system applications is discussed. Furthermore, future trends in analysis, design, and evaluation of distributed energy storage system for the power grid using power-electronic-intensive interface are identified.

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Contents

I. Introduction

Transportation and electric power generation are the two major consumers of fuel. Constantly increasing price of fuel and global warming are the major motives to improve the efficiency and fuel economy of the vehicle fleet as well as the electric power generation [1]–[4]. Furthermore, with heavier power transfers, power systems are increasingly vulnerable to cascading failures. The power grid of the future needs to be more reliable and secure [5]. Integration of the vehicle fleet with the power grid has not been effectively investigated. Plug-in hybrids and vehicle to grid concepts [6] have been independently introduced; however, minimum effort has been done to systematically combine these two concepts and if none, there have been minor efforts on the identification of the required cyberinfrastructure of the future vehicle to grid concept.

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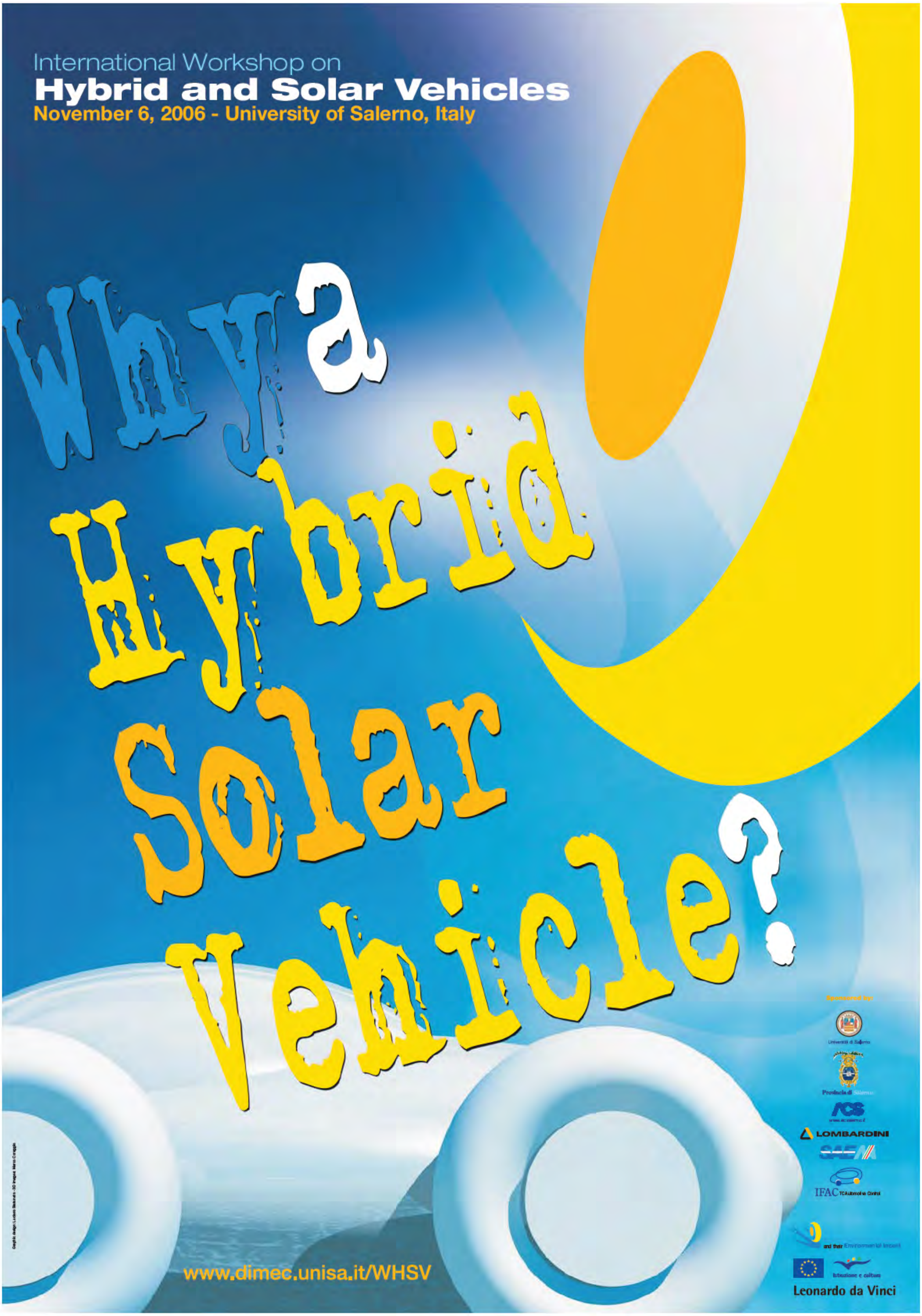
Appendix LETENDRE05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PREFACE

The growth of mobility has had a positive effect on prosperity and quality of life, but its negative impact on the environment and the erosion of non-renewable resources are becoming more and more visible. As a consequence, the attention toward the sustainable mobility is rapidly increasing, spreading from specialists to final users and to public opinion. In last decade, the hybrid electric vehicles have emerged as a valid mid-term solution to reduce fuel consumption and carbon dioxide emissions. Their integration with photo-voltaic sources may give a further contribution toward the mitigation of fossil fuels depletion, global warming and climate changes. Despite these promising perspectives, there is a certain lack of systematic research on the integration of hybrid vehicle technology with solar sources.

This Workshop is dedicated to hybrid and solar vehicles, with particular emphasis on the combined use of these two approaches. These proceedings include 13 papers, from Hungary, France, Italy, Romania, Spain, Turkey and United States. Most of the research presented is conducted in an academic context, also in cooperation with industry and research centres. The papers cover several aspects of hybrid and solar vehicles. The actual trends and the opportunities related to the integration of electric vehicles with photo-voltaic and, more generally, with renewable sources are presented in the first paper. Five papers deal with modelling, design and control of hybrid solar vehicles, also caring for profitableness of such vehicles. Other five papers concern hybrid electric vehicles: hybridization of a small vehicle for urban transportation and of a 4WD parallel vehicle, control of super-capacitors, HEV real-time control and performance testing. Other two papers are devoted to photovoltaic sources for automotive applications, concerning MPPT modelling and power interfaces.

I would thank all the Authors for their dedication in preparing excellent technical papers, the members of Scientific Committee for their cooperation in paper review and my colleagues at the University of Salerno for their help in the Workshop organization. We acknowledge the financial and operative support of University of Salerno to this Workshop, co-sponsored by the Technical Committee “Automotive Control” of International Federation of Automatic Control and by SAE Naples Section. We also recognize the significant impulse given to the studies on hybrid solar vehicles by the European Community in supporting the Leonardo Project “Engine Conversion Systems and Their Enviromental Impact”, with sponsorship of Automobile Club Salerno, Lombardini, Saggese and Province of Salerno.

The Workshop Chair

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Prof. Gianfranco Rizzo, DIMEC, University of Salerno (I), grizzo@unisa.it

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CONTENTS

USHERING IN AN ERA OF SOLAR-POWERED MOBILITY

Steven E. Letendre, Ph.D.

Green Mountain College, Poultney, VT &
The Prometheus Institute for Sustainable Development, Cambridge, MA, USA
Letendre@vermontel.net

Abstract: Modern mobility, for both humans and commodities, relies almost exclusively on fuels derived from petroleum. At the same time the world is experiencing soaring demand for mobility, environmental and resource constraints have become increasingly acute. This article discusses the role that electric drive, initially in the form of hybrid electric vehicles, can play in addressing the mobility challenge. This article discusses the opportunity that electric drive vehicles create to use solar and wind power for transportation. The potential of the emerging vehicle integrated PV concept is discussed, along with the importance of connecting cars to the electric grid.

Keywords: electric vehicles, solar energy, renewable energy systems, electric power systems

1. MOBILITY IN THE 21ST CENTURY

Human progress is tied to advances in mobility. Societies adept at harnessing technology to reduce the travel times to distant lands successfully gained access to new resources, allowing wealth creation opportunities beyond which local resources allowed. The process accelerated dramatically as fossil fuels were employed to provide even greater opportunities to move people and commodities across great distances.

Today, mobility is a commodity for which demand is linked closely to income. Specifically, increases in demand for highway travel and air travel in a country tracks closely growth in national income. Figure 1 provides data on per capita vehicle miles travelled (VMT) and per capital air travel from 1960 to 2004 in the US. During this timeframe per capita income grew from $13,800 to $38,856 while per capita VMT more than doubled and per capita domestic air travel quadrupled. Based on the experiences in the US, per capita VMT took approximately 30 years to double, while per capita domestic miles flown doubled in just ten years.

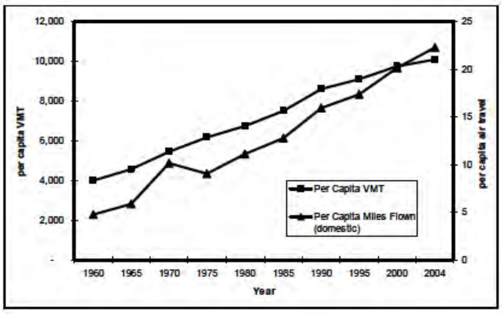

Fig. 1. Mobility trends in the US: Per capita vehicles miles travelled and per capita domestic air travel, 1960 to 2004 (Sources: US Bureau of Economic Statistics and the US Bureau of Transportation Statistics)

As incomes in the developing world rise, demand for mobility likewise increases in these regions. Myer and Kent (2003) in their book *New consumers: The influence of affluence on the environment* highlight the rapid increase in demand for personal automobiles occurring in the developing world and in countries as a new consumer class emerges. They argue that over 1 billion of these new consumers will soon have an aggregate spending capacity, in purchasing power parity terms, to match that of the US. Recent data suggests that China is rapidly expanding its automobile manufacturing capabilities; annual passenger production grew from 100,000 vehicles in 1991 to 2.3 million in 2004—a 28 fold increase (Worldwatch Institute, 2006).

We have reached an apex in global mobility. The shear volume and pace of movement, of both humans and commodities, on this planet is incomprehensible. The 3.7 trillion passenger-kilometers of air travel in 2005 equals over four and a half million round trips from the Earth to the Moon (ICAO, 2005).

What made this level of mobility possible, and how much longer can it be sustained? This critical question is addressed in the next section of the article.

1.1 Petroleum and transportation: resource constraints, the environment, & supply risks

Petroleum-derived fuels, such as gasoline for vehicles and jet fuel for modern aircraft, provide over 97% of primary energy for transportation. Of the 80 million barrels used globally each day in 2003, approximately one half are consumed for transportation. The US Department of Energy's Energy Information Administrations (EIA) predicts that global oil consumption will reach 118 million barrels per day by 2030 (EIA, 2006). In sum, transportation is entirely dependant on a single source of energy—petroleum—and its consumption for transportation purposes is predicted to rise by 47% in twenty-five years. Most of this increase will come from rising demand for transportation in non-OECD countries (EIA, 2006).

The state of modern transportation systems is extremely precarious. Relying exclusively on petroleum as a source of energy for transportation creates significant risks, the most important of which is resource limits. Volumes have been written about the so called peak oil phenomenon, which suggests that global oil production peaks and subsequently enters a prolonged period of decline. While oil does not "run out" many predict that prices rise dramatically in the face of rising demand and declining production (Simmons, 2005). While the timing of peak oil is the subject of debate, it's generally accepted that it will occur within the first half of this century.

The use of petroleum for transportation is a factor linked to global climate change. The combustion of fuels for transportation causes carbon dioxide emissions, the primary pollutant contributing to global warming, into the atmosphere. Approximately 25% of global emissions of carbon dioxide come from the transport sector. In addition, transport related emissions are one of the fastest growing categories, which is likely to increase the share of total carbon emissions coming from the transport sector.

A number of recent scientific studies suggest that global climate change is occurring more rapidly than scientists predicted and is already having negative impact on ecosystems across the globe. Governments and non-governmental organizations worldwide are calling for dramatic reductions in carbon dioxide emissions to minimize further warming of the Earth and the associated consequences of rising sea levels, more severe weather patterns, and negative ecosystem impacts. Clearly, efforts are needed to reduce the transport-related emissions of carbon; this can only be accomplished by either reducing the amount of travel, increasing the efficiency of the vehicle fleet, shifting toward alternative fuels, or some combination there of.

Supply risks are an additional concern linked to the transport sector's exclusive reliance on oil as a primary energy source. Roughly one-third of global oil production comes from the politically volatile Middle East (EIA, 2006). Furthermore, this region is home to the largest known oil reserves, thus the region will become increasingly important as a global supplier. The region is currently enmeshed in several armed conflicts, including the conflict between the US and Iraq. Terrorist attacks on key ports and escalating regional violence could cause significant supply shocks.

2. TOWARD SUSTAINABLE MOBILITY

The scope of the mobility challenge is daunting. The issue must be addressed on multiple fronts, from smart planning to reduce the need for travel by automobiles to the development of new vehicle technologies.

The remainder of this article focuses specifically on options to reduce the light vehicle fleet's dependence on petroleum-derived fuel sources. This is achieved through either improving fuel economy and/or using alternative fuels. Progress has been made in these areas, but virtually all vehicles commercially available today run primarily on either gasoline or diesel fuel.

In the US, the primary mechanism for regulating vehicle fuel economy is the Corporate Average Fuel Economy (CAFE) standard, established at the national level. These standards remain unchanged since 1985 at 27.5 miles per gallon (mpg). Europe is further along in addressing the mobility challenge with more developed mass transit systems and a much more efficient light vehicle fleet than that found in the US.

The search for viable alternative fuels has focused on biofuels, with interest in biofuels surging in recent years. Brazil is often held up as a successful example of large-scale biofuel development, meeting 20% of its transport fuel requirements with ethanol derived from sugar cane. The development of flex-fuel vehicles in the US is gaining momentum, which provides a vehicle owner a choice of energy options to meet their transportation needs. For example, some automobile manufacturers are building vehicles that operate on biofuel blends like E85—a blend of 85% ethanol and 15% gasoline.

Biofuels offer the potential to reduce our dependence on gasoline for the light vehicle fleet, but the potential is limited. There is much debate about the energy balance of biofuels and the appropriateness of using arable land to produce energy crops as apposed to food. It is unlikely that biofuels will emerge as a replacement for gasoline as a transport fuel, although they could serve to displace a small portion of gasoline and diesel fuel for the light vehicle fleet.

Much effort is being directed at producing fuel cells for mobile applications, fuelled with onboard compressed hydrogen. Fuel cell vehicles running on compressed hydrogen are viewed by some as the ultimate means to achieve sustainable mobility. In recent years, however, some have questioned the over emphasis on research and development in to fuel cell vehicles and their potential to reduce carbon emissions in the short-term. It is becoming increasingly clear that hydrogen-powered fuel cells vehicles face a number of technical and economic challenges that will likely take decades to address (Morris, 2003).

In a 2004 report prepared by the US-based Center for Energy and Climate Solutions for the National Commission on Energy Policy concluded, "**We believe that the most plausible vehicle of the future is a plug-in hybrid running on a combination of low-carbon electricity and a low-carbon biomass-derived fuel.**" (Center for Energy and Climate Solutions, 2004)

2.1 The hybrid electric vehicle revolution

Hybrid electric vehicles (HEV), using both an internal combustion engine and electric motor, achieve dramatic improvements in fuel economy. Commercially available HEVs boast fuel economy ratings of over 50 mpg. For example, the most popular hybrid, the Toyota Prius, achieves a fuel economy rating of 60 mpg highway and 51 mpg city.

Consumers now have several HEV options to choose from, and their popularity among the car-buying public is increasing. Virtually every major automobile manufacturer is manufacturing, or plans to in the near future, HEVs. In 2005, HEVs reached 1.2% of new cars sold in the US, more than doubling the number sold in the prior year. Toyota is the leading manufacturer of HEVs, globally selling over 50% of all hybrids purchased in the US in 2005.

The evolution of HEVs to allow charging from the electric grid, so called plug-in hybrids (PHEV), is assumed by many to be desirable—some may argue inevitable. Ultimately, the economics of displacing gasoline with electricity should drive consumer demand for PHEVs. The cost of electricity to drive a vehicle the same distance as one gallon of gasoline is equal to approximately $1—or even less if off-peak electricity prices are assumed (Denholm and Short, 2006). Furthermore, as discussed later in this article, PHEVs could potentially generate revenue for the vehicle owner by providing grid support services. Combined, these value propositions could serve to usher in an era of advanced vehicles with dramatic reductions in gasoline use and tailpipe emissions.

A growing, national movement to bring PHEVs to the market has emerged in the US, bolstered by the undeniable economic and national security benefits that result from displacing gasoline with electricity. One highly-visible, grass-roots campaign, called Plug-In Partners, seeks to demonstrate to the major automobile manufacturers that a national market exists for flexible-fuel PHEVs; dozens of businesses, utilities, municipal governments, and environmental groups have joined the Plug-In Partners campaign.

While there are no commercially available PHEVs on the market, a number of prototypes have been built and tested. The most established PHEV program is housed at the University of California Davis, where Professor Andrew Frank works with students designing and building prototype PHEVs. A second development project involves collaboration between the Electric Power Research Institute and DaimlerChrysler. They produced, and are in the process of testing, several prototype plug-in hybrid vans using the Sprinter platform. Two start-up firms plan to offer conversion kits for current generation hybrid electric vehicles to allow grid charging of the on-board battery pack. These conversions kits offer the potential to almost double an HEV's fuel efficiency rating to 100+ miles per gallon by increasing the size of the battery storage system and installing the hardware and controls to allow charging from the electric grid.

3. HYBRIDS AND RENEWABLES: EXPLORING THE POTENTIAL

As the vehicle fleet moves toward electric drive, initially in the form of HEVs, the opportunity for renewables, beyond biofuels, to serve as an energy source for the transport sector emerges. This opportunity is greatly enhance when vehicles connect to the grid to charge an onboard battery pack. The remainder of this article explores this opportunity from the emerging vehicle integrated concept (VIPV) to the role that wind can play in powering grid-connected cars.

Hybrids electric vehicles with the capability to recharge from the electric grid dramatically reduce the needed liquid fuels for transportation. Studies have found that most vehicles could meet the vast majority of their daily commute with a PHEV designed with a 40 mile all electric range. Thus, PHEVs can exploit wind and solar as a fuel source and at the same time dramatically reduce liquid fuel requirements. It becomes more realistic for biofuels to meet the lower liquid fuel requirements needed as the vehicle fleet relies to a greater degree on electricity.

3.1 The Solar Hybrid Electric Vehicle

In 2003, the author presented the vehicle integrated photovoltaic (VIPV) concept to an American audience at the annual meeting of the American Solar Energy Society. The paper titled, *Vehicle integrated PV: A clean and secure fuel for hybrid electric vehicles* argued that HEVs create an opportunity for PV to serve as an energy source for the transport sector.

Until recently, PV has not been considered a viable energy source for vehicles. Some experiments were conducted using PV for electric vehicle (EV) charging, but efforts to commercialize have stalled due to the perceived lack of market acceptance for these types of vehicles. Other efforts to deploy PV for transportation have taken place at a variety of university research centers, where teams of students and faculty build vehicles powered solely from solar. These vehicles are designed and built to compete in solar car races such as the World Solar Challenge, which began in Australia in 1987. These vehicles were never intended for commercial production, the futuristic look and design of these experimental vehicles would not likely appeal to mass markets.

Since the 2003 conference, the author learned of a variety of projects to advance the VIPV concept. Researchers at the University of Queensland in Australia are developing a commuter hybrid vehicle with PV integrated in to the body panels. An engineer in Canada installed a 270 watt solar array on the roof of his Toyota Prius, increasing the mileage by approximately 10%. Even the major auto manufacturers are eyeing the VIPV opportunity, with both Ford, and its close corporate partner Mazda, displayed hybrid vehicles with modest amounts of VIPV at recent auto shows. The author produced a second article on the topic highlighting recent VIPV activities, which appeared in the May/June 2006 edition of Solar Today.

In October of this year, the French specialty vehicle manufacturer Venturi Automobiles announced plans to offer the first commercially available solar hybrid sports car called the Astrolab. The company also produces an urban electric commuter vehicle called the Eclectic. The 3-seater vehicle has solar PV integrated on to the roof of the vehicle. Venturi claims that this is the first energy-autonomous vehicle available to the public.

Pic. 1. PV integrated Toyota Prius, Lapp Renewables LTD, 2005

Pic. 2. Venturi Automobiles' Astrolab, the first commercially available PV integrated hybrid

Pic. 3. Venturi Automobiles' Eclectic, the first energy autonomous electric urban commuter vehilce

Recently, Taiwan's PV cell manufacturer E-Ton Solar announced a joint venture with several partners, including Yulon Nissan Motor Co., Ltd. to develop PV products for the car market. The joint venture began with the manufacturing of PV modules for car sunroofs.

3.2 Design Considerations for Solar Hybrids

Given current HEV designs, VIPV could serve to enhance the overall efficiency of the vehicle, but only provide a small portion of the vehicle's energy requirements. In this context, VIPV is similar to regenerative breaking, which, through converting the kinetic energy lost in breaking to electrical energy, serves to enhance the overall efficiency of an HEV. A number of design and engineering considerations could serve to increase PV's role in fuelling a new generation of solar hybrid vehicles

The key parameters dictating VIPV's ability to displace gasoline for transportation are the quantity of PV in watts integrated on to the body panels and the efficiency of the vehicle drivetrain. The amount of PV that can be integrated on to a vehicle is a function of the available space and the efficiency of the PV technology deployed. Venturi Automobile's Astrolab mentioned above contains 3.6 m^2 of PV integrated on to the vehicle. Measurements of the available surface area of a number of conventional vehicles suggest available surface areas of between 3.5 m^2 to 5.5 m^2 (Letendre et al., 2006). Figure 2 indicates potential PV in watts for three different scenarios of available surface by PV conversion efficiencies.

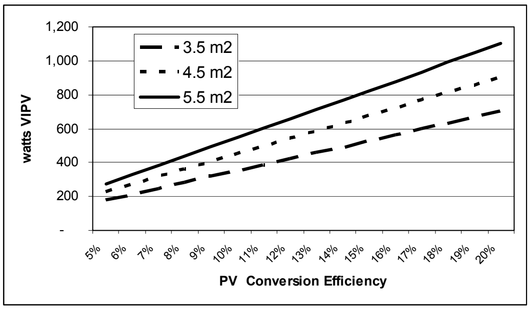

Fig. 2. VIPV watts potential: surface area vs. PV sunlight to electricity conversion efficiency

As Figure 2 illustrates, the sunlight to conversion efficiency of the PV technology deployed in VIPV applications is an important parameter. While flat plate silicon PV has high conversion efficiencies, thin film PV may be better suited for VIPV applications. Again referring back to Venturi Automobile's Astrolab, the vehicle uses high efficiency monocrystaline PV cells to achieve 600 watts of PV on the available 3.6 m^2 of surface area. Copper indium gallium diselenide (CIGS) solar cells, which are not yet fully commercial, offer both advantages of flexibility like other thin film PV technologies, but with much higher conversion efficiencies. One US company, DayStar Technologies, is nearing commercial-scale production of a CIGS PV product on flexible steel. Generally, the US is leading in the development of the next generation PV technology, which should be predominantly flexible thin films.

It should be noted that the onboard PV capacity may not necessarily be constrained by the available surface area on the vehicle's body panels, but flexible PV could be used to design retractable solar shades that could be deployed when the vehicle is parked to provide additional PV capacity for daytime charging.

The efficiency of the vehicle drivetrain determines the number of solar miles obtained from any given VIPV system. Current hybrids, like the Toyota Prius have all electric efficiencies in the 156 watt-hours per kilometer range. Figure 3 illustrates solar miles for a 500 watt VIPV system in a region with an average of 4 sun hours per day for total annual PV generation of 710 kWh.

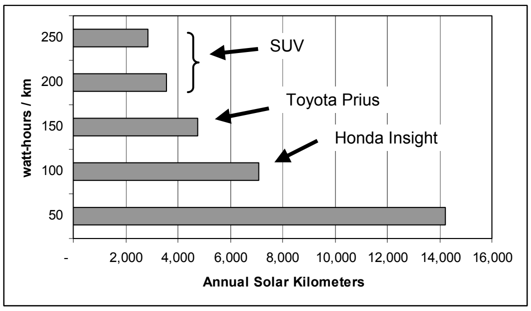

Fig. 3. VIPV watts potential: surface area vs. PV sunlight to electricity conversion efficiency

Advances in the use of lightweight materials for vehicles will serve to increase the potential solar miles delivered from a VIPV system. However, even today's commercially available hybrid can benefit from VIPV. Initial VIPV applications will provide incremental improvements in vehicle efficiency, but the future potential is much greater. The Leonardo Project, sponsored by the European Commission, aims to train a new generation of engineers in sustainable transportation focused initially on designing and building a solar hybrid. This project, and other like it, will serve to advance knowledge on these concepts and ultimately achieve advanced designs that dramatically improve existing technologies and approaches.

Battery storage devices are a critical enabling technology for the solar hybrid revolution. While many advances have been made in battery technology, reductions in price and improvements in performance are needed to produce commercially viable solar hybrid vehicles.

A promising new battery technology was unveiled at the September 2006 California Air Resources Board Zero Emission Vehicles Symposium. Navada-based Altairnano announced a new lithium ion battery system called NanoSafe™, which replaces graphite as the electrode materials with nano-titanate materials (www.altairnano.com). The company claims that this new materials solve the thermal runaway problem with conventional lithium ion batteries, and offer significant improvements in cycle life and delivers optimum energy/power balance in the high power region, which is critical for hybrid and electric vehicle applications.

3.3 Plug-In Hybrids Facilitates the Use of Wind for the Transport Sector

While both conventional HEVs and PHEVs can adopt a VIPV strategy allowing for the use of solar for transportation, only plug-in hybrids facilitate the use of wind power for transportation purposes.

Wind power is the fasting growing new source of power generation world-wide. In the US alone the American Wind Energy Association estimates that over 3,000 MW of new wind will go on line in 2006. Globally, estimates of installed wind power capacity reached 60,000 MW in 2005 (Worldwatch Institute, 2006). Wind power is a clean and renewable source of power generation that will continue to expand in the coming years.

The intermittent nature of wind power creates challenges for developers seeking to integrate wind into electric grids and wholesale markets. At low wind power penetration rates intermittency is less of an issue; however, as wind plays an increasingly important role in the global supply mix, intermittency will need to be addressed. The variability of output from wind farms creates challenges given the existing electric industry structure, which is characterized by scheduled flows of power from sources to sinks. The cost and environmental characteristics, however, are sufficiently compelling that regulations have been devised to facilitate wind power integration in to the electric supply mix.

The variability of wind power can be understood in discrete categories based on increasingly longer time intervals that characterize the market strategy that is needed to manage the variability as more and more wind appears on the electric network. These categories are:

- Minute to hour variability, addressed through regulation markets, intra-hour adjustments, or spinning reserves.
- Hour to day, addressed through operating reserves (spinning and non-spinning reserves)
- 1-4 days, dispersion of wind resources with transmission, operating reserves, load management, and dedicated storage (Kempton and Tomic, 2005a)

Recent analyses suggest that the emergence of PHEVs and other electric vehicles could serve to address the intermittency challenge associated with wind and other intermittent resources like solar (Letendre et al., 2002; Kempton and Tomic, 2005a, and Denholm and Short, 2006). In one of these studies Kempton and Tomic (2005a) calculate that that electric vehicles with onboard battery storage and bi-directional power flows could stabilize large-scale (one-half of US electricity) wind power with 3% of the fleet dedicated to regulation for wind, plus 8–38% of the fleet providing operating reserves or storage for wind.

At a minimum, the nature of PHEV charging complements the intermittent nature of wind power. Given the high periods of non-use of vehicles, PHEVs represent a new source of load, unlike critical loads like computers and other information technologies, which doe not require a constant flow of power for re-charge. The charging of PHEVs can be modulated as the power production from a wind farm varies. This serves to address the first tear of intermittency (variability) described earlier. I envision new power contracts between PHEV owners and developers of wind farms. The complementary nature of wind power and PHEVs creates an opportunity to further enhance the environmental character of PHEVs through wind power charging.

To address the second and third tiers of wind power variability described earlier, PHEVs would require reverse flow capabilities. This concept has become widely known as the vehicle to grid (V2G) concept, which is covered extensively in the next section of this article. Millions of PHEVs connected to the electric grid would represent a very large aggregate energy storage resource. Figure 4 indicates the amount of storage that would be connected to the grid for PHEVs with various electric only ranges (from 20 to 60 miles) by the number of vehicles. Even at small penetration rates in the new car market PHEVs could offer a significant storage capacity to address wind power's longer duration variability.

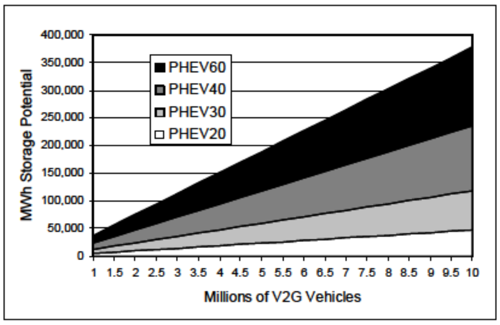

Fig. 4. PHEV energy storage potential

It's quite possible that VIPV, wind power charging, and ethanol or biodiesel could create the first mass market, mobility solution that is 100% renewable. This mobility system becomes even more attractive when understood in the context of the emerging vehicle to grid concept. Next, I turn to this topic and describe the benefits that are possible as the transport and electric power sectors converge.

4. V2G: INTEGRATING THE TRANSPORT AND ELECTRIC POWER SECTORS

As the vehicle fleet moves toward electric drive, initially in the form of HEVs, interesting synergies can be exploited between the transport and the electric power sectors when a bi-directional grid interface is built. In aggregate, grid-connected cars would represent a potentially large and highly reliable power resource to the electric power sector. This opportunity was first explored by Kempton and Letendre in a 1997 article published in *Transportation Research-D.*

The light vehicle fleet and the electric power system represent two massive energy conversion systems, which evolved in isolation from each other over the past century. The electric power system relies on thousands of generating units which convert stored energy (chemical [coal, natural gas, oil], mechanical [hydro and wind], and nuclear) in to alternating current that flows across a massive interconnected transmission and distribution grid to final end users. In contrast, the light vehicle fleet coverts petrochemical energy to rotary motion and then to travel. A massive petroleum, refining, and transport infrastructure exists to support the light vehicle fleet's energy needs.

The electric power industry is unique in that the product, electricity, is produced and consumed at the same time. There is virtually no storage in the system; except for pumped hydro in select locations. Grid operators must continuously match supply and demand by turning on and off generators in response to demand. In contrast the light vehicle fleet requires storage, given that its fuel must be mobile and thus is carried onboard in a storage container. As the light vehicle fleet migrates toward electric drive, storage energy in onboard batteries serves to supplement the stored energy in the vehicle's fuel tank.

Electric generators are designed for high duty cycles, in the US average utilization rates of the nation's generating assets reaches 60%. In contrast, as mentioned above, vehicles are in use approximately 5% of the time. While electric generators can take minutes or hours to deliver power to the grid, electric drive vehicles could deliver power to the grid virtually instantaneously.

In aggregate these complementary characteristics of the electric power sector and the light vehicle fleet offer a compelling reason to evaluate the integration of these systems as vehicle technology migrates toward electric drive. Through a bi-directional interface, grid-connected cars could deliver power when called upon by a central grid operator. Figure 5 illustrates schematically the vehicle to grid (V2G) concept. Advances and cost reductions in wireless communications would allow a central operator to dispatch stored energy in vehicles upon demand. In Figure 5 the Independent System Operator (ISO) is delivering a dispatch signal to those vehicles connected to the grid and prepared to deliver power at a moments notice.

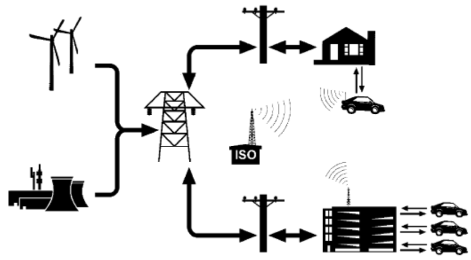

Fig. 5. Schematic of vehicle to grid concept (Kempton and Tomic, 2005a)

Even at small fractions of the vehicle fleet, electric drive vehicles could represent a very large power resource. At 10 kW per vehicle, one million vehicles represent 10,000 MW of available V2G power; the current global vehicle fleet is estimated to be over 600 million vehicles (Worldwatch Institute, 2006).

4.1 V2G Research Finding

The author knows of just one V2G demonstration project (Brooks, 2002). The demonstration project was conducted by a California-based electric vehicle development company AC Propulsion, in conjunction with the California Independent System Operator (ISO). AC Propulsion produces the only V2G capable electric vehicle drivetrain. For the demonstration project a Volkswagen Beetle was converted to a pure electric vehicle outfitted with AC Propulsion's bi-directional charger and a communication link with the California ISO. They successfully demonstrated the remote dispatch of power from a parked electric vehicle in response to a signal from the ISO.

Most of the research to date on V2G involves modelling and economic analyses. One comprehensive study, for which the author was involved, was funded by the California Air Resources Board. Although no technical barriers were discovered in the research, a number of key issues were identified that bear on the economic value of V2G power services.

Research on this topic suggests that V2G capable cars are best suited to provide grid services that require a rapid response, but our used for a short duration. The limited onboard energy storage of an electric drive vehicle is not suited for providing base-load power. The most promising markets for V2G power fall under the heading of ancillary services—services purchased by grid operators to maintain system reliability. The two most valuable ancillary services in the US are for regulation (frequency response) and spinning reserves. Economic analyses demonstrate that a single vehicle can generate hundreds of dollar annually providing these services (Letendre and Kempton, 2002).

A second important issue for V2G capable cars, which determines the potential revenue from providing grid services, is the power output that can be sustained by a vehicle providing ancillary services. Kempton and Tomic (2005b) identify three key factors that limit the amount of power a grid-connected car can deliver back to the grid. These include the on board vehicle electronics, capacity of the plug circuit, and energy storage capacity and state of charge when the vehicle is plugged in to provide grid services.

A PHEV's vehicle's power electronics should not create a binding limit on the amount of power that can be exported to the grid. PHEVs require high power components for acceleration and to optimize vehicle performance. The electric drivetrain developed and manufactured by AC Propulsion mentioned earlier provides 80 amps in either direction, allowing 19.2 kW of power output. Thus, the critical factors dictating the reverse power potential come down to the capacity of the plug circuit and the size and state of charge of the PHEV's battery pack.

Given the evidence on the V2G potential today, the next logical step would be a large-scale demonstration project. A fleet of say 100 electric drive vehicles equipped with a bi-directional charger could serve to resolve some issues that would give the private sector more confidence in pursuing the V2G business opportunity. In the end, the revenue that V2G could generate would help to overcome the price premium for the first-generation plug-in hybrids or pure electric vehicles, thus ushering in a new era of clean, flexible fuel vehicles.

As experience is gained and the price of electric drive vehicles declines, their use in providing peak power and storage for intermittent renewables is more likely. Furthermore, an increasingly fleet of V2G capable vehicles could eventually enhance the overall reliability of the grid and support a more environmentally sound electric supply mix.

5. CONCLUSION

As we enter the early stages of the 21st Century, society has reached an apex in mobility. The global economy is poised precariously on continues flows of people and goods, made possible by an abundant and cheap source of energy—oil! Recent events suggest that this critical resource is no longer abundant and cheap. In 2006, petroleum reached record prices on international exchanges of over $70 per barrel. Some of the world's most renowned petroleum geologists are warning that we are quickly approaching the point at which we have extracted approximately one half of the existing oil reserves buried deep in the Earth crust—the so called peak oil event.

These, and other critical geopolitical events, suggest that society must rapidly pursue the development of alternative means of transportation to maintain even a portion of the mobility we have come to rely upon in this modern ear. It's becoming increasingly clear that electric drive will play a central role in the future vehicle fleet. Already, today hybrid electric vehicles (HEVs) have gained commercial success. Many groups are actively pursuing the logical evolution of HEVs to allow charging from the electric grid. Others are focused on hydrogen as the primary energy carry for transportation, fuelling a future fleet of fuel cell vehicles. Regardless of the technology that dominates the future, vehicle will rely increasingly on electric drive and contain significantly more onboard battery storage than today's fleet of internal combustion engines.

This new era of electric drive vehicles allows for renewables, beyond biofuels, to serve as an energy source for the light vehicle fleet. Vehicle integrated PV and grid-connected cars charging from wind power become real possibilities as hybrid electric vehicles emerge as viable alternatives to internal combustion vehicles. There is tremendous momentum in this direction as research organizations, governments, and private industry seek to solve our immanent mobility crisis. A French specialty automobile company plans to offer the first commercial solar hybrid to consumers. E-Ton Solar, a major PV manufacturer, has entered a joint venture to develop products specifically for the car market.

Finally, the V2G concept is the ultimate vision whereby the transport and electric power sector converge and reap tremendous efficiencies while improving reliability, reducing pollution, and delivering greater energy security to those nations with the foresight to seize this opportunity.

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Appendix WILLIAMS01

Title

Commercializing Light-Duty Plug-In/Plug-Out Hydrogen-Fuel-Cell Vehicles:"Mobile Electricity" Technologies, Early California Household Markets, and Innovation Management

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by

BRETT DAVID WILLIAMS
B.A. (Pomona College) 1994
M.Phil. (Cambridge University) 1995

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Transportation Technology & Policy

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

Approved:

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Committee in Charge

2007

Dissertation overview

Starting from the premise that new consumer value must drive hydrogen-fuel-cell-vehicle (H_2FCV) commercialization, a group of opportunities collectively called “Mobile Electricity” is characterized. Mobile Electricity (Me-) redefines H_2FCVs as innovative products able to import and export electricity across the traditional vehicle boundary. Such vehicles could provide home recharging and mobile power, for example for tools, mobile activities, emergencies, and electric-grid-support services. To characterize such opportunities, this study first integrates and extends previous analyses of H_2FCVs, plug-in hybrids, and vehicle-to-grid (V2G) power. It uses a new electric-drive-vehicle and vehicular-distributed-generation model to estimate zero-emission-power vs. zero-emission-driving tradeoffs, costs, and grid-support revenues for various electric-drive vehicle types and levels of infrastructure service.

Next, the initial market potential for Me-enabled vehicles, such as H_2FCVs and plug-in hybrids, is estimated by eliminating unlikely households from consideration for early adoption. 5.2 million of 33.9 million Californians in the 2000 Census live in households pre-adapted to Me-enabled vehicles, 3.9 million if natural gas is required for home refueling. The possible sales base represented by this population is discussed. Several differences in demographic and other characteristics between the target market and the driving-age population are highlighted, and two issues related to the design of H_2FCVs and their supporting infrastructure are discussed: vehicle range and home hydrogen refueling. These findings argue for continued investigation of this and similar target segments—which represent more efficient research populations for subsequent study by product designers and other decision-makers wishing to understand the early market dynamics facing Me- innovations.

Next, Me-H_2FCV commercialization issues are raised from the perspectives of innovation, product development, and strategic marketing. Starting with today's internal-combustion hybrids, this discussion suggests a way to move beyond the battery vs. fuel-cell zero-sum game and towards the development of integrated plug-in/plug-out hybrid platforms. H_2FCVs are described as one possible extension of this Me- product platform for the supply of clean, high-power, and profitable Me- services as the technologies and markets mature.

Finally, the major findings of this study are summarized and directions for future work discussed. Together, the parts of this Mobile Electricity innovation assessment reveal an initially expensive and limited but compelling (and possibly necessary) set of opportunities to help drive H_2FCV and other electric-drive-vehicle commercialization.

Keywords: Hydrogen-fuel-cell vehicle, Mobile Electricity innovation, Plug-in hybrid, Plug-out hybrid, Vehicle-to-grid power, Vehicular distributed generation, Household market potential, product development, market development

Table of contents

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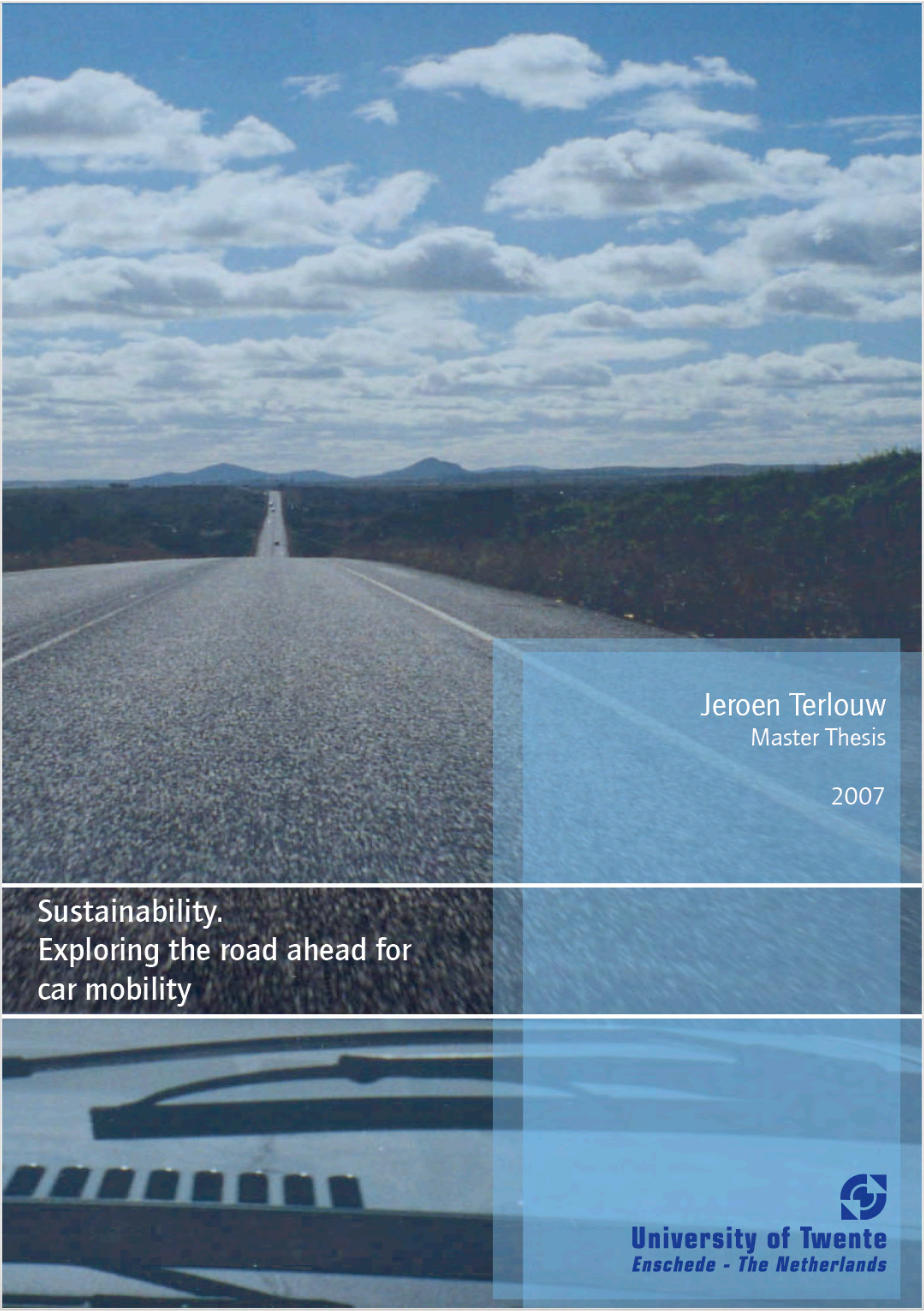
Appendix TERLOUW01



Jeroen Terlouw
Master Thesis

2007

Sustainability. Exploring the road ahead for car mobility

University of Twente
Enschede - The Netherlands

Master thesis 2007

Sustainability.
Exploring the road ahead for car mobility

Student:	Jeroen Terlouw (s0071420)
University:	University of Twente (UT)
Study:	Civil Engineering and Management
Subject:	Transport Engineering and Management
Contact:	jeroen.terlouw@gmail.com

Committee:	
Supervisor (UT):	Prof. Dr. Ir. M.F.A.M.Van Maarseveen
Supervisor (MNP):	Drs. A. Hoen
Reader (UT):	Ing. K. M. Van Zuilekom

28/08/2007, Enschede/Bilthoven

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Appendix ROMM01

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Viewpoint

The car and fuel of the future

Joseph Romm*,[1]

Center for Energy and Climate Solutions, 2900 South Quincy Street, Suite 410, Arlington, VA 22206, USA

Available online 8 August 2005

Abstract

This paper is based on a review of the technical literature on alternative fuel vehicles (AFVs) and discussions with experts in vehicle technology and energy analysis. It is derived from analysis provided to the bipartisan National Commission on Energy Policy.

The urgent need to reverse the business-as-usual growth path in global warming pollution in the next two decades to avoid serious if not catastrophic climate change necessitates action to make our vehicles far less polluting.

In the near-term, by far the most cost-effective strategy for reducing emissions and fuel use is efficiency. The car of the near future is the hybrid gasoline–electric vehicle, because it can reduce gasoline consumption and greenhouse gas emissions 30 to 50% with no change in vehicle class and hence no loss of jobs or compromise on safety or performance. It will likely become the dominant vehicle platform by the year 2020.

Ultimately, we will need to replace gasoline with a zero-carbon fuel. All AFV pathways require technology advances and strong government action to succeed. Hydrogen is the most challenging of all alternative fuels, particularly because of the enormous effort needed to change our existing gasoline infrastructure.

The most promising AFV pathway is a hybrid that can be connected to the electric grid. These so-called plug-in hybrids or e-hybrids will likely travel three to four times as far on a kilowatt-hour of renewable electricity as fuel cell vehicles. Ideally these advanced hybrids would also be a flexible fuel vehicle capable of running on a blend of biofuels and gasoline. Such a car could travel 500 miles on 1 gal of gasoline (and 5 gal of cellulosic ethanol) and have under one-tenth the greenhouse gas emissions of current hybrids.

Keywords: Alternative fuels; Hydrogen; Hybrids

1. Introduction

Any energy and environmental policy effort must come to grips with transportation. Roughly 97% of all energy consumed by our cars, sport utility vehicles, vans, trucks, and airplanes is still petroleum-based.

In the 1990s, the transportation sector saw the fastest growth in carbon dioxide emissions of any major sector of the US economy. And the transportation sector is projected to generate nearly half of the 40% rise in US carbon dioxide emissions forecast for 2025 (EIA, 2005).

Internationally, the situation is equally problematic. As Claude Mandil, Executive Director of the International Energy Agency (IEA), said in May 2004, "In the absence of strong government policies, we project that the worldwide use of oil in transport will nearly double between 2000 and 2030, leading to a similar increase in greenhouse gas emissions" (IEA, 2004)

Significantly, between 2003 and 2030, over 1400 GW of new coal capacity will be built. These plants would commit the planet to total carbon dioxide emissions of

*Tel.: +1 202 270 6213; fax: +1 202 483 1062.

E-mail address: jromm007@aol.com.

[1]Joseph Romm is a former Acting Assistant Secretary at the US Department of Energy's Office of Energy Efficiency and Renewable Energy, which oversees federal alternative fuel vehicle research and deployment. He is author of The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate, named one of the best science and technology books of 2004 by Library Journal. He holds a Ph.D. in physics from MIT.

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some 500 billion metric tons over their lifetime, unless "they are backfit with carbon capture equipment at some time during their life," as David Hawkins, Director of Natural Resources Defense Council's Climate Center told the US House Committee on Energy and Commerce in June 2003. Hawkins continued: "To put this number in context, it amounts to half the estimated total cumulative carbon emissions from all fossil fuel use globally over the past 250 years!" (Hawkins, 2003)

It is critical that whatever strategy the world adopts to reduce GHG emissions in the vehicle sector does not undermine our efforts to reduce GHG emissions in the electricity sector. With this caveat in mind, I explore some of the pathways most widely discussed for reducing or replacing oil while significantly reducing transportation greenhouse gas emissions: efficiency, electricity (particularly plug-in hybrid-gasoline vehicles); ethanol from cellulosic biomass; and hydrogen.

2. Alternative fuels and alternative fuel vehicles

Alternative fuel vehicles (AFVs) and their fuels face two central problems. First, they typically suffer from several marketplace disadvantages compared to conventional vehicles running on conventional fuels. Hence, they inevitably require government incentives or mandates to succeed. Second, they typically do not provide cost-effective solutions to major energy and environmental problems, which undermines the policy case for having the government intervene in the marketplace to support them.

On the second point, in September 2003, the US Department of Transportation Center for Climate Change and Environmental Forecasting released its analysis, Fuel Options for Reducing Greenhouse Gas Emissions from Motor Vehicles. The report assesses the potential for gasoline substitutes to reduce greenhouse gas emissions over the next 25 years. It concludes that "the reduction in GHG emissions from most gasoline substitutes would be modest" and that "promoting alternative fuels would be a costly strategy for reducing emissions" (DOT, 2003).

The US government and others (such as of California and Canada) have tried to promote AFVs for a long time. The 1992 Energy Policy Act established the goal of having alternative fuels replace at least 10% of petroleum fuels in 2000, and at least 30% in 2010. Currently, alternate fuels consumed in AFVs substitute for under 1% of total consumption of gasoline. A significant literature has emerged explaining this failure (GAO, 2000, Flynn, 2002). Besides the question of whether AFVs deliver cost-effective emissions reductions, there have historically been six major barriers to AFV success:

1. high first cost for vehicle
2. on-board fuel storage issues (i.e. limited range)
3. safety and liability concerns
4. high fueling cost (compared to gasoline)
5. limited fuel stations: chicken and egg problem
6. improvements in the competition (better, cleaner gasoline vehicles).

All AFVs that have so far been promoted with limited success electric vehicles, natural gas vehicles, methanol vehicles, and ethanol vehicles have each suffered from several of these barriers. Any one of these barriers can be a showstopper for an AFV or an alternative fuel, even where other clear benefits are delivered. MTBE, for instance, has had its biggest difficulty with the safety and liability issue, even though it has minimal problems in the other areas because it can be blended directly with gasoline. Electric vehicles deliver the clear benefit of zero tailpipe emissions, and can even have lower per mile costs than gasoline cars, but range, refueling, and first-cost issues have limited their success and caused most major auto companies to withdraw their electric vehicles from the marketplace.

The chicken and egg problem who will build and buy the AFVs if a fueling infrastructure is not in place and who will build the fueling infrastructure before the AFVs are built remains the most intractable barrier. Consider that there are millions of flexible fuel vehicles already on the road capable of running on E85 (85% ethanol, 15% gasoline), 100% gasoline, or just about any blend, for about the same price as gasoline-powered vehicles, and yet the vast majority of them run on gasoline and there are have been very few E85 stations built.

In the case of natural gas light-duty vehicles, the environmental benefits were oversold, as were the early cost estimates for both the vehicles and the refueling stations: "Early promoters often believe that 'prices just have to drop' and cited what turned out to be unachievable price levels." One study concluded, "Exaggerated claims have damaged the credibility of alternate transportation fuels, and have retarded acceptance, especially by large commercial purchasers" (Flynn, 2002).

All AFVs face the increasing "competition" from improved gasoline-power vehicles. Indeed, two decades ago when tailpipe emissions standards were being developed requiring 0.02 g/mile of NO_x, few suspected that this could be achieved by internal combustion engine vehicles running on reformulated gasoline.

The new generation of hybrid PZEVs such as the Toyota Prius and Ford Escape hybrid have substantially raised the bar for future AFVs. These vehicles have no chicken and egg problem (since they can be fueled everywhere), no different safety concerns than other gasoline cars, a substantially *lower* annual fuel bill, *greater* range, a 30% to 50% reduction in greenhouse gas emissions, and a 90% reduction in tailpipe emissions. The vehicles do cost a little more, but that is more than offset by the current government incentive and the large reduction in gasoline costs, even ignoring the performance benefits. Compare that to many AFVs, whose environmental benefits, if any, typically come at the expense not merely of a higher first cost for the vehicle, but a much higher annual fuel bill, a reduced range, and other undesirable attributes from the consumer's perspective.

2.1. Hydrogen

Widespread use of stationary fuel cells running on natural gas seems likely post-2010, particularly if high-temperature fuel cells achieve their cost and performance targets. The transition to a transportation system based on a hydrogen economy will, however, be much slower and more difficult than widely realized.

In particular, it is unlikely that hydrogen vehicles will achieve significant (>5%) market penetration by 2030. A variety of major technology breakthroughs and government incentives will be required for them to achieve significant commercial success by the middle of this century. Continued R&D in hydrogen and transportation fuel cell technologies remains important because of their potential to provide a zero-carbon transportation fuel in the second half of the century. But neither government policy nor business investment should be based on the assumption that these technologies will have a significant impact in the near- or medium-term.

Bill Reinert, US manager of Toyota's advanced technologies group said in January 2005, absent multiple technology breakthroughs, we won't see high-volume sales of fuel cell vehicles until 2030 or later (Truett, 2005). When Reinert was asked when fuel cells cars would replace gasoline-powered cars, he replied "If I told you '*never*,' would you be upset?" (Butters et al., 2005).

Hydrogen cars face enormous challenges in overcoming each of the major historical barriers to AFV success.

The central challenge for any AFV seeking government support beyond R&D is that the deployment of the AFVs and the infrastructure to support them must cost effectively address some energy or environmental problems facing the nation. Yet in the spring issue of Issues and Science and Technology, two hydrogen experts, Dan Sperling and Joan Ogden of U.C. Davis, wrote, "Hydrogen is neither the easiest nor the cheapest way to gain large near- and medium-term air pollution, greenhouse gas, or oil reduction benefits"(Sperling and Ogden, 2004). A 2004 analysis by the Pacific Northwest National Laboratory and the University of Maryland concluded that even "in the advanced technology case with a carbon constraint … hydrogen doesn't penetrate the transportation sector in a major way until *after 2035*"(Geffen et al., 2004). A push to constrain carbon dioxide emissions actually delays the introduction of hydrogen cars because sources of zero-carbon hydrogen such as renewable power can achieve emissions reductions far more cost-effectively simply replacing planned or existing coal plants. As noted above, our efforts to reduce GHG emissions in the vehicle sector must not come at the expense of our efforts to reduce GHG emissions in the electric utility sector.

In fact, Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context, a January 2004 study by the European Commission Center for Joint Research, the European Council for Automotive R&D, and an association of European oil companies, concluded that using hydrogen as a transport fuel might well *increase* Europe's greenhouse gas emissions rather than reduce them (JRC, 2004). That is because many pathways for making hydrogen, such as grid electrolysis, can be quite carbon-intensive and because hydrogen fuel cells are so expensive that hydrogen internal combustion engine vehicles may be deployed instead (which is already happening in California). Using fuel cell vehicles and hydrogen from zero-carbon sources such as renewable power or nuclear energy has a cost of avoided carbon dioxide of more than $600 a metric ton, which is more than a factor of ten higher than most other strategies being considered today.

A number of major studies and articles have recently come out on the technological challenges facing hydrogen. Transportation fuel cells currently cost about $4000/kW, some 100 times greater than the cost of internal combustion engines (Wald, 2004). A 2004 article for the Society of Automotive Engineers noted, "Even with the most optimistic assumptions, the fuel cell powered vehicle offers only a marginal efficiency improvement over the advanced [diesel]-hybrid and with no anticipation yet of future developments of IC engines. At $100/kW, the fuel cell does not offer a short-term advantage even in a European market" (Oppenheim and Schock, 2004).

A prestigious National Research Council panel concluded a major report in February 2004 with a variety of important technical conclusions (NRC, 2004). For instance, the panel said, "The DOE should halt efforts on high-pressure tanks and cryogenic liquid storage…. They have little promise of long-term practicality for light-duty vehicles." A March 2004 study by the American Physical Society concluded that "a new material must be discovered" to solve the storage problem (APS, 2004). An analysis in the May 2004 issue of Scientific American stated, ''Fuel-cell cars, in contrast [to hybrids], are expected on about the same schedule as NASA's manned trip to Mars and have about the same level of likelihood'' (Wald, 2004).

There is a tendency in analyses of a future hydrogen economy to assume the end state mass production of low-cost fuel cells, pipeline delivery, and so on. Yet while transportation fuel cells would undoubtedly be far cheaper if they could be produced at quantities of one million units per year, the unanswered question is who will provide the billions of dollars in subsidies during the many years when vehicle sales would be far lower and vehicle costs far higher. And while pipelines are the desired end game, and ''the costs of a mature hydrogen pipeline system would be spread over many years,'' as the National Research Counicl panel noted, ''the transition is difficult to imagine in detail'' (NRC, 2004). The AFV problem is very much a systems problem where the transition issues are as much of the crux as the technological ones. We believe all AFV analysis should be conservative in nature, stating clearly what is technologically and commercially possible today, and, when discussing the future, be equally clear that projections are speculative and will require both technology breakthroughs and major government intervention in the marketplace. Analysis should treat the likely competition fairly: If major advances in cost reduction and performance are projected for hydrogen technologies, similar advances should be projected for hybrids, batteries, biofuels, and the like.

Hydrogen fuel cell vehicles face major challenges to overcome each and every one of the barriers discussed earlier. It is possible we may never see a durable, affordable fuel cell vehicle with an efficiency, range, and annual fuel bill that matches even the best *current* hybrid vehicle. Of all AFVs and alternative fuels, fuel cell vehicles running on hydrogen are probably the least likely to be a cost-effective solution to global warming, which is why the other pathways deserve at least equal policy attention and funding.

2.2. E-hybrids

One AFV, however, has clear environmental benefits, including substantially lower greenhouse gas emissions, a much lower annual fuel bill, a much longer range than current cars (with the added ability to fuel at home), and far fewer infrastructure issues than traditional AFVs. This AFV is the plug-in hybrid, also called the e-hybrid.

A straightforward improvement to the current generation of hybrids can allow them to be plugged into the electric grid and run in an all-electric mode for a limited range between recharging. Since most vehicle use is for relatively short trips, such as commuting, followed by an extended period of time during which the vehicle is not being driven and could be charged, even a relatively modest all-electric range of 20 or 40 miles could allow these vehicles to replace a substantial portion of gasoline consumption and tailpipe emissions. If the electricity were from CO_2-free sources, then these vehicles would also have dramatically reduced net greenhouse gas emissions.

Because they have a gasoline engine, and are thus a duel-fuel vehicle, e-hybrids avoid two of the biggest problems of pure electric vehicles. First they are not limited in range by the total amount of battery charge. If the initial battery charge runs low, the car can run purely on gasoline and on whatever charging is possible from the regenerative braking. Second, electric vehicles take many hours to charge, so that if for some reason owners were unable to allow the car to charge either because they lacked the time between trips to charge or there was no local charging capability then the pure-electric car could not be driven. Thus, e-hybrids combine the best of both hybrids and pure electric vehicles.

Battery improvement will lead to increased functionality for e-hybrids. Improvements in specific energy (Wh/kg) and specific power (W/kg) will reduce weight. Reductions in cost and increases in cycle life (durability) will make PHEVs more affordable. Adequate safety is a requirement. Operating temperature is important, but batteries with unusual operating temperatures may be considered if other benefits are demonstrated. Convenience of recharging is crucial, but the definition of ''convenience'' varies by users. A full recharge overnight from an ordinary home outlet is generally considered to be sufficient for a personal e-hybrid.

2.3. Barriers

E-hybrids avoid many of the barriers to AFVs discussed earlier. They do not have a limited range. They do not have major safety and liability issues although great care would have to be taken in the design of any home-based system that charged e-hybrids or allowed them to feed back into the grid. They do not have a high fueling cost compared to gasoline. In fact, the per-mile fueling cost of running on electricity is about one-third the per-mile cost of running on gasoline. The chicken and egg problem is minimized because electricity is widely available and charging is relatively straightforward.

The vehicle will almost certainly have a higher first cost, but this is likely to be more than compensated by the economic benefit of a lower fuel bill, as a 2003 study by the California Energy Commission and California Air Resources Board concluded (CEC and CARB, 2003). Also, that study did not consider a large potential revenue stream the vehicle owner may be able to extract from the utility by having what is essentially a portable electric generator.

An e-hybrid owner may be able to extract revenue for grid regulation services generators that can provide fast response when grid voltage needs to be increased or decreased. Utilities would pay for this service if there was a guarantee that the car could deliver juice when needed, which suggests that this is more practical for vehicle fleets or for a corporate sponsor. The potential value of such services is significant: $700 to $3000 per year (Letendre and Kempton, 2002). This value is so large that it might allow the monthly cost of purchasing or leasing an e-hybrid to be *lower* than a conventional car, and perhaps even cover the replacement cost for batteries if they prove not to have a 100,000 + mile lifetime typically expected of modern cars. It is critical that we fund some real-world demonstrations of e-hybrids providing these services, to see if this value can be extracted. If it can, we might see major utilities helping to subsidize the cost and/or financing of e-hybrids.

Environmentally, e-hybrids offer two potentially significant benefits. First, since they are designed to run all-electric for short trips such as commuting, they offer the possibility of being zero-emission vehicles (ZEVs) in cities. The best early uses of e-hybrids may well be to replace dirty diesel engine vehicles used regularly in cities, such as buses, maintenance vehicles, and delivery trucks. If we are unable to overcome the multiple technical and practical hurdles to hydrogen fuel cell cars, then e-hybrids may be the only viable option for urban zero emission vehicles.

The potential greenhouse gas benefits of e-hybrids are even more significant, if a source of zero-carbon electricity can be utilized for recharging. E-hybrids have an enormous advantage over hydrogen fuel cell vehicles in utilizing zero-carbon electricity. That is because of the inherent inefficiency of generating hydrogen from electricity, transporting hydrogen, storing it onboard the vehicle, and then running it through the fuel cell. The total well-to-wheels efficiency with which a hydrogen fuel cell vehicle might utilize renewable electricity is roughly 20% (although that number could rise to 25% or a little higher with the kind of multiple technology breakthroughs required to enable a hydrogen economy). The well-to-wheels efficiency of charging an onboard battery and then discharging it to run an electric motor in an e-hybrid, however, is 80% (and could be higher in the future) four times more efficient than current hydrogen fuel cell vehicle pathways.

As Dr. Alec Brooks, who led the development of the Impact electric vehicle has shown, "Fuel cell vehicles that operate on hydrogen made with electrolysis consume *four times as much* electricity per mile as similarly sized battery electric vehicles" (Brooks, 2004).

Ulf Bossel, founder of the European Fuel Cell Forum, comes to a similar conclusion in a recent article, "The daily drive to work in a hydrogen fuel cell car will cost four times more than in an electric or hybrid vehicle" (Bossel, 2004).

This relative inefficiency has enormous implications for achieving a sustainable energy future. To replace half of US ground transport fuels (gasoline and diesel) in the year 2050 with hydrogen from wind power, for example, might require 1400 GW of advanced wind turbines or more. To replace those fuels with electricity in e-hybrids might require under 400 GW of wind. That 1000 GW difference may represent an insurmountable obstacle for hydrogen as a GHG mitigation strategy especially since the US will need several hundreds of gigawatts of wind and other zero-carbon power sources in 2050 just to sharply reduce GHG emissions in the electricity sector.

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Appendix ROMM02

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Viewpoint

The car and fuel of the future

Joseph Romm [1]

Center for Energy and Climate Solutions, 2900 South Quincy Street, Suite 410, Arlington, VA 22206, USA

Available online 8 August 2005.

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Abstract

This paper is based on a review of the technical literature on alternative fuel vehicles (AFVs) and discussions with experts in vehicle technology and energy analysis. It is derived from analysis provided to the bipartisan National Commission on Energy Policy.

The urgent need to reverse the business-as-usual growth path in global warming pollution in the next two decades to avoid serious if not catastrophic climate change necessitates action to make our vehicles far less polluting.

In the near-term, by far the most cost-effective strategy for reducing emissions and fuel use is efficiency. The car of the near future is the hybrid gasoline–electric vehicle, because it can reduce gasoline consumption and greenhouse gas emissions 30 to 50% with no change in vehicle class and hence no loss of jobs or compromise on safety or performance. It will likely become the dominant vehicle platform by the year 2020.

Ultimately, we will need to replace gasoline with a zero-carbon fuel. All AFV pathways require technology advances and strong government action to succeed. Hydrogen is the most challenging of all alternative fuels, particularly because of the enormous effort needed to change our existing gasoline infrastructure.

The most promising AFV pathway is a hybrid that can be connected to the electric grid. These so-called plug-in hybrids or e-hybrids will likely travel three to four times as far on a kilowatt-hour of renewable electricity as fuel cell vehicles. Ideally these advanced hybrids would also be a flexible fuel vehicle capable of running on a blend of biofuels and gasoline. Such a car could travel 500 miles on 1 gal of gasoline (and 5 gal of cellulosic ethanol) and have under one-tenth the greenhouse gas emissions of current hybrids.

Introduction

Any energy and environmental policy effort must come to grips with transportation. Roughly 97% of all energy consumed by our cars, sport utility vehicles, vans, trucks, and airplanes is still petroleum-based.

In the 1990s, the transportation sector saw the fastest growth in carbon dioxide emissions of any major sector of the US economy. And the transportation sector is projected to generate nearly half of the 40% rise in US carbon dioxide emissions forecast for 2025 (EIA, 2005).

Internationally, the situation is equally problematic. As Claude Mandil, Executive Director of the International Energy Agency (IEA), said in May 2004, “In the absence of strong government policies, we project that the worldwide use of oil in transport will nearly double between 2000 and 2030, leading to a similar increase in greenhouse gas emissions” (IEA, 2004)

Significantly, between 2003 and 2030, over 1400 GW of new coal capacity will be built. These plants would commit the planet to total carbon dioxide emissions of some 500 billion metric tons over their lifetime, unless “they are backfit with carbon capture equipment at some time during their life,” as David Hawkins, Director of Natural Resources Defense Council's Climate Center told the US House Committee on Energy and Commerce in June 2003. Hawkins continued: “To put this number in context, it amounts to half the estimated total cumulative carbon emissions from all fossil fuel use globally over the past 250 years!” (Hawkins, 2003)

It is critical that whatever strategy the world adopts to reduce GHG emissions in the vehicle sector does not undermine our efforts to reduce GHG emissions in the electricity sector. With this caveat in mind, I explore some of the pathways most widely discussed for reducing or replacing oil while significantly reducing transportation greenhouse gas emissions: efficiency, electricity (particularly plug-in hybrid-gasoline vehicles); ethanol from cellulosic biomass; and hydrogen.

Section snippets

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1 Joseph Romm is a former Acting Assistant Secretary at the US Department of Energy's Office of Energy Efficiency and Renewable Energy, which oversees federal alternative fuel vehicle research and deployment. He is author of The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate, named one of the best science and technology books of 2004 by Library Journal. He holds a Ph.D. in physics from MIT.

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