ESTABLISHMENT AND DEVELOPMENT OF CALIFORNIA'S FUEL CELL ELECTRIC VEHICLE MARKET - LESSONS LEARNED FOR THE EU MEMBER STATES

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Overview

As countries and regions pursue climate change mitigation, the importance of decarbonizing the transportation sector through green hydrogen utilization, produced via renewable energy sources, becomes evident [1,2]. This shift necessitates modifications to public policies and strategies enacted by regional and central/federal authorities [3]. Simultaneously, the drive for transportation decarbonization has prompted innovation in the automotive sector, resulting in an array of zero- or low-emission vehicles like Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs), and Fuel Cell Electric Vehicles (FCEVs). Examining each vehicle type individually is crucial, given their diverse and competitive markets. Despite PHEVs and BEVs dominating the electric car market [4], FCEVs hold significant potential for transportation decarbonization. Various countries and regions have adopted differing public policy incentives and strategies to promote FCEVs with mixed success [5]. Over the past decade, California has displayed diverse strategies [6,7] and a growing FCEV market potential in light-duty passenger vehicles, buses, and medium- and heavy-duty vehicles [8,9]. This expansion has coincided with the development of publicly accessible hydrogen refueling infrastructure and increased green hydrogen production, transportation, and storage. Given this context, the research problem can be framed as follows: **How have state policy instruments impacted California's fuel cell electric vehicle market development from 1990 to 2022, and what lessons can be drawn for the EU member states?**

Methods

In this study, I employed a mixed-method approach to investigate the public policy instruments used in shaping California's fuel cell electric vehicle (FCEV) market development over the past decades. First, I conducted a critical review and analysis of the existing scientific literature to synthesize state-of-the-art research on the topic. To supplement these findings, I analyzed recent secondary data, including statistics, reports, and market publications related to the research problem, through desk research. This analysis of key FCEV market indicators provided a comprehensive overview of the changes from 1990 to 2022. Furthermore, a comparative analysis of state-level public policy statements, bills, and directives was carried out to gain a deeper understanding of the adopted assumptions and review the implemented instruments. Lastly, I conducted highly structured interviews with various FCEV market stakeholders, such as policymakers, researchers, and representatives from companies and organizations involved in sustainable and low-carbon hydrogen production, hydrogen refueling infrastructure operation, and supply- and demand-side market actors. These 46 interviews were transcribed and evaluated using NVivo software to generate insightful results.

Results

The research results allow the evaluation of public policy instruments implemented in California from 1990 to 2022. The fundamentally effective instruments were those implemented on the state level. I identified four strategic objectives and matching policy instruments which are as follows: **(1) sustainable and low-cost production of hydrogen** (most effective policy instruments were: *Hydrogen Fuel Specifications and the 33% Green Hydrogen Requirement* as regulations and standards*; Low Carbon Fuel Standard* as tradebale permits), **(2) developing accessible and reliable refuelling infrastructure** (most effective policy instruments were: *AFV and Fuelling Infrastructure Grants* as subsidies; *Station Building Standards and Safety Codes* as regulations and standards; and *ZEV Infrastructure Support, Hydrogen Fuelling Station Evaluation* as the information policies), **(3) growth of market supply for FCEV** (most effective policy instruments were: *Light-, Medium-, and Heavy-Duty ZEV Requirements* as regulations and standards, *and ZEV Production Requirements* as tradeble credits), and last but no least objective **(4) growth of market demand for FCEV** (most effective policy instruments were: *Advanced Transportation Tax Exclusion, Zero Emission Transit Bus Tax Exemption, and ZEV Fee* as tax incentives, *Purchase requirements for Zero-Emission Transit Bus, Airport Shuttle, and Public Fleet Vehicles* as regulations and standards, *Bus Replacement Grants, LD-ZEV Rebates, HVIP Vouchers, and Emissions Reductions Grants* as subsidies, and *High Occupancy Vehicle and High Occupancy Toll Lane Exemption* as information policies). The strength of impact and effectiveness of these individual policy instruments were also evaluated with the quantitative approach during the interviews by assigning the weights of impact to present the overall road map for FCEV market growth in these four critical strategic development areas.

The research also discusses and demonstrates the essential role of demonstration projects, such as the example of the Port of Los Angeles, where heavy-duty FCEVs are operating. The research results contribute to a better understanding of the applied public policy instruments' effectiveness in deploying hydrogen and fuel cell technologies in California's transportation sector.

Conclusions

In conclusion, this analysis of California's successful fuel cell electric vehicle (FCEV) market development offers valuable insights for EU member states seeking to promote their own FCEV markets. First, adopting a technology-neutral policy approach with ambitious goals ensures fair competition and innovation across various vehicle technologies. Second, fostering synergy across FCEV market segments can lead to a more cohesive and robust market. Third, prioritizing the development of reliable, accessible, and high-capacity refueling stations is essential for encouraging FCEV adoption. Fourth, demonstrating a long-term commitment to supporting FCEVs can help circumvent the "valley of death" faced by emerging technologies. Fifth, promoting the scalability potential of FCEVs, particularly within transit agencies and medium- to heavy-duty fleets, can further drive market growth. Sixth, implementing policies based on tradable credits, subsidies, and purchase requirements can incentivize both supply and demand for FCEVs. Finally, establishing a self-sustaining regional hydrogen ecosystem, such as a hydrogen hub or hydrogen valley, can contribute to a comprehensive and effective infrastructure. By embracing these lessons learned from California's experience, EU member states can create a conducive environment for FCEV market development, fostering sustainable transportation and contributing to a greener future.

IAEE Codes:

10.6. Transportation – Policy Issues.
10.3. Transportation - Electric vehicles & systems.

References

[**1**] Hydrogen Council (2017). How hydrogen empowers the energy transition. Retrieved from: https://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf

[**2**] International Renewable Energy Agency (2020). *Green hydrogen: A guide to policymaking*. IRENA: Abu Dhabi.

[**3**] Victor, D.G., Geels, F.W. & Sharpe, S. (2019). *Accelerating the Low Carbon Transition: The Case for Stronger, More Targeted and Coordinated International Action.* Brookings Ltd.: Washington DC.

[**4**] International Energy Agency. (2019). *Global EV Outlook 2019*. IEA: Paris.

[**5**] Bose-Styczynski, A., & Hughes, L. (2019). Public policy strategies for next-generation vehicle technologies: An overview of leading markets. *Environmental Innovation and Societal Transitions 31*, pp. 262-272.

[**6**] Brown, T., Shane S.-R., & Samuelsen G. S. (2012). Quantitative analysis of a successful public hydrogen station, *International Journal of Hydrogen Energy 37* (17), pp. 12731-12740.

[**7**] Schoenung, S.M., & Keller, J.O. (2017). Commercial potential for renewable hydrogen in California, *International Journal of Hydrogen Energy 42* (19), pp. 13321-13328.

[**8**] Trencher, G. (2020). Strategies to accelerate the production and diffusion of fuel cell electric vehicles: Experiences from California. *Energy Reports 6*, pp. 2503-2519.

[**9**] Forrest, K., MacKinnon, M., Tarroja, B., & Samuelsen, S. (2020). Estimating the technical feasibility of fuel cell and battery electric vehicles for the medium- and heavy-duty sectors in California. *Applied Energy 276*, 115439.

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EDUCATION

Doctoral School **2019 – present**
Wrocław University of Economics and Business, Wrocław - **Ph.D. studies in Economics and Finance**

Postgraduate studies in Data Science **2021 – present**
University of Warsaw, Warsaw
Field of specialization: Data Science in business and research applications in R

Master in Economics with the Business Individualized Studying Program **2017 – 2019**
Wrocław University of Economics and Business, Wrocław
Field of specialization: *Market analysis.*
MA thesis: "Shaping the development of Polish economy by 2020 in the light of new structural economics assumptions."

Academy of Young Diplomats
European Academy of Diplomacy, Warsaw **2016 – 2017**
Postgraduate diplomatic studies,
Field of specialization: *Polish Foreign Service*

Bachelor in Economics **2014 – 2017**
Wrocław University of Economics and Business with the **Erasmus+ exchange at the University of Porto, Portugal**
Field of specialization: *Market analysis.*
BA thesis: "The role of fiscal policy instruments in shaping regional development."

RESEARCH INTERESTS

- Evaluation of the renewable energy and environmental policies and strategies on the regional level in the USA, EU and Japan by applying the econometric approach and a case study method in the field of energy transition and hydrogen economy.
- Analysis of the cluster policy in the area of innovative power generation technologies, including hydrogen and fuel cells.
- Studies of the alternative energy transition models in the Asia-Pacific region and their impact on the economic development, trade and the energy sectors' structure of the national economies.

RESEARCH EXPERIENCE

Research project manager **2019 – present**
- Research project manager of the four research projects financed by the INTEREKON Program, National Academic Exchange Agency and the Faculty of Economics and Finance.
- Participant in the research projects conducted in the Department of International Business at the home University.
- Co-organizer and participant of cross-departmental seminars and workshops for graduate students and faculty members.

Research assistant in the Asia-Pacific Research Center **2020 – present**
- Research assistant in the projects focused on the institutional determinants of trade relations in the Asia-Pacific countries in the context of power generation products, including photovoltaics and wind turbines.
- Co-author of the case study research focused on the EU and Polish cybersecurity policies in the context of economic security.
- Coordinator of the submission and publication process of the APRC works (i.e., monographs).
- Co-organizer of the 10th International Asia-Pacific conference at the home university (November 2021).

TEACHING EXPERIENCE

Guest lecturer at the University of Wrocław, Institute of International Studies **2021 – present**
- Lecturer of the university classes in *Fundamentals of Environmental Economics* (in English) and *International Market Competitiveness* (in Polish), thanks to the invitation from the Director of the Institute of International Studies.

Research assistant and Ph.D. candidate **2019 – present**
Wrocław University of Economics and Business
- Co-author of the International Business Simulation Game in Virtual Reality (VR), where IB students gain new competencies in coordinating a company's production, logistics and export of photovoltaic cells. IB students can simulate different scenarios of a company's internationalization and demonstrate their knowledge and skills in the VR simulation.
- Conducted university classes in *International Business* and *International Economic Relations*. Starting from the summer semester of 2021/2022 academic year, he will also lead academic courses in *International Energy Markets* and *Data Science in International Business*.

Workshops on project management and leadership for high school students **2019 – 2021**
- Trainer, initiator and organizer of the workshops for the high school students in local municipalities in the Lower Silesia Voivodship.

HONORS AND SCHOLARSHIPS

Fulbright-Schuman Award 2022/2023 **2022 – 2023**
Scholarship from the Fulbright Commission in Belgium and the European Commission for the research on hydrogen economy at the University of California, San Diego in the Center for Global Transformation and Deep Decarbonization Initiative.

TopMinds 2021 **2020 - 2021**
Participant of a one-year academic mentoring program for selected Ph.D. students co-organized by the Polish-U.S. Fulbright Commission and Top500 Innovators Association that offered workshops, training and a platform for debates. *Academic mentor*: prof. Beata Bochorodycz.

Member of the International Association for Energy Economics (IAEE) **2021 – present**

EIASM International Doctoral Seminar **2020**
Participant of the 5-week series of the international "EDEN doctoral seminars on generating impactful research ideas for young scholars." co-organized by the European Institute for Advanced Studies in Management and the Academic Creativity Labs, Brussels (ONLINE).

Konrad Adenauer Stiftung and **Kazimir Pulaski Foundation** **2016**
Received a joint scholarship for admission to the postgraduate studies at the European Academy of Diplomacy, Warsaw (only four scholarships were granted that year).

RESEARCH GRANTS

Fulbright-Schuman Award 2022/2023 **2022**

"Deployment of the hydrogen and fuel cell technologies in California's energy and transportation sectors. Evidence from the case study research, short-term forecast and evaluation of California's public policies in 2008-2022 – as compared to strategies adopted in the EU, precisely in Poland and Germany.", (August 2022 – January 2023).

Intercollegiate Research Grant **2022**

"Polish economy in the face of new challenges in the third decade of the 21st century" in cooperation with the researchers from Warsaw School of Economics and the home University. My area of expertise covers the energy sector challenges.

Faculty of Economics and Finance Research Grant (WUEB) **2021**

"An econometric gravity trade model of the photovoltaic cells export in the Asia-Pacific region, with a view at the role of regional trade agreements and national energy transition policies." Research in cooperation with Dr. Andrzej Tomski, Silesian University in Katowice.

Young Researcher Grant, INTEREKON Program – program financed by the Polish Ministry of Science and Higher Education 2020 -2021

(1) "The impact of China's policy on the wind energy sector development - an econometric approach with the dynamic regression model."
(2) "Forecasting the near future development of the Chinese wind energy sector using ARIMA, grey model and artificial neural network".
Research in cooperation with Dr. Andrzej Tomski, Silesian University in Katowice.
(3) "The analysis of hydrogen and fuel cells cluster potential development in the Lower Silesia region based on structured interviews".

National Academic Exchange Agency (NAWA), PROM Program **2020**

Recipient of the scholarship for a one-month research internship at the Peking University (Beijing, China) under Professor Justin Yifu Lin's supervision. "The role of the new structural economics postulates in shaping renewable energy sector development – case study approach with the structured interviews" – Autumn 2022 (postponed due to COVID-19 pandemic restrictions).

RECENT PUBLICATIONS

Brusiło P., Drelich-Skulska B. (2021). Hydrogen transformation of the European Union and Poland *Impakt Dolny Śląsk 2*. The think-tank of Wroclaw University of Economics and Business.

Brusiło P. (2021). Evaluation of China's policy for wind power development from the new structural economics perspective. *International Journal of Sustainable Energy Planning and Management 32,* pp. 19–36.

Drelich-Skulska B., Brusiło P. (2021). From Cybersecurity to Economic Security. The EU and Polish Perspective [in:] Drelich-Skulska B., Okawara M. (eds.) *Current Trends in the Global Economy. From the Perspective of Japanese and Polish Economists.* Wrocław: WUEB Publishing House.

Brusiło P. (2021). The Chinese photovoltaic cells industry and the Belt and Road Initiative – the intra-industry perspective. [in:] Ujwary-Gil A., Godlewska-Dzioboń B. (eds.) *Challenges in Economic Policy, Business, and Management in the COVID-19 era.* Warsaw: Institute of Economics, Polish Academy of Sciences.

Brusiło P., Drelich-Skulska B. (2021). Photovoltaic cells industry in China. Industrial policy and revealed comparative advantage in the XXI century. [in:] Ujwary-Gil A., Godlewska-Dzioboń B. (eds.) *Challenges in Economic Policy, Business, and Management in the COVID-19 era.* Warsaw: Institute of Economics, Polish Academy of Sciences.

Brusiło P. (2019). Transition towards energy generation from renewable energy sources in People's Republic of China. *Economics of the 21st Century 2*, pp. 85-97.

RECENT CONFERENCE AND WORKSHOP PRESENTATIONS (in 2021)

Brusiło P., Drelich-Skulska B. (2021). *Photovoltaic cells industry growth in China and its revealed comparative advantage from the new structural economics perspective in 2000 – 2019.* The 20th International Conference of the Japan Economic Policy Association at the University of Tokyo.

Brusiło P. (2021). *Policy for wind power development in China from the new structural economics perspective – econometric approach.* The 5th Annual Conference of the Portuguese Association of Energy Economics (APEEN) and International Association for Energy Economics (IAEE), Lisbon, Portugal.

Brusiło P., Drelich-Skulska B. (2021). *Photovoltaic cells industry in China and the Belt and Road Initiative – the intra-industry perspective.* The 20th Jubilee Conference of Scientists and Business Professionals, Institute of Economics, Polish Academy of Sciences, Warsaw, Poland.

Brusiło P. (2021). *Development of the Asia-Pacific energy sector in the time of COVID-19 pandemic crisis.* 10th International Asia-Pacific Conference of the Asia-Pacific Research Centre at the Wrocław University of Economics and Business.

Brusiło P. (2021). *The global pursuit of energy transition towards renewable energy sources*. Presentation at the international doctoral seminar organized by the Wrocław University of Economics and Business.

INSTITUTIONAL SERVICE

- Member of the Doctoral School Council and the official representative of the Ph.D. students community at the home University.
- Coordinator of the cooperation between the University and the European Commission in the field of organizing a series of scientific conferences and public debates on the European Green Deal and implementation of the EU climate policy.

PROFESSIONAL EXPERIENCE

Communication specialist (as the external employee) **2018 / 2019**

Regional Representation of the European Commission, Wrocław, Poland

- Guided workshops and lectures about the EU structure and functioning.
- Organized scientific conferences and debates with the high-rank EU officials (i.e., the conference titled: *The floods and droughts - how to shape regional development in harmony with nature*)
- Gave radio and TV stations interviews and moderated public debates in the Representation of the European Commission.

COMMUNITY INVOLVEMENT

Regional Youth Parliament of Lower Silesia Voivodship **2013 – 2020**

Coordinator of youth projects, team leader, organizer of workshops and conferences. Honorary Member and Advisor, President of the Youth Parliament**,** President of the Committee of International Cooperation.

Youth Regional Network of the Assembly of European Regions (AER) **2014 – 2018**

Project leader, youth delegate and representative of the Lower Silesian youth, President of the Committee of Entrepreneurship and Professional Life.

RESEARCH QUALIFICATIONS AND SKILLS

- Econometric and statistical analysis using advanced Data Science tools and programming in R.
- Data collection and analysis of information from primary and secondary sources.
- Interviewing and polling (with structured and semi-structured interviews)
- Presenting research outcomes at the conferences and reporting the results to the supervisor.