Project WTP:
What Drives the Willingness to Pay for Low-Carbon Fuel

Final Report

APRIL 23, 2025

Re-cap: Project objectives and key questions

Project objectives and priorities

- To evaluate the degree of **public support** for policies mandating low-carbon fuel
- To assess the possibility of a **"tipping point"** where voters may push back on low-carbon fuel policies
- Columbia team to focus on **qualitative study**, which complements [CLIENT]'s quantitative simulations

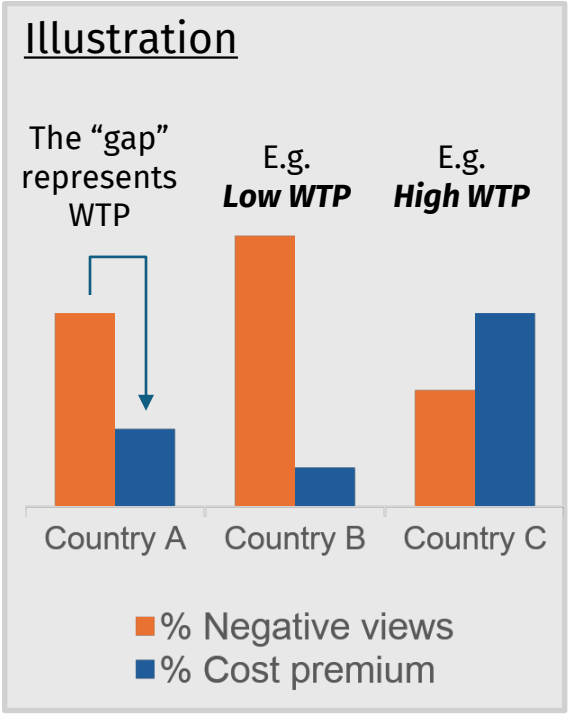
Key questions

- What are the **main contexts** in which people discuss about low-carbon LCF?
- How do the public in major markets view LCF? **Interest level? Positive views vs. Negative views?**
- How do public willingness-to-pay (WTP) **evolve over time?** What **drives** the changes?
- Any **regional differences** by market?
- What are the **key indicators** for LCF players to watch?

The “WTP Index” assesses the willingness-to-pay and its drivers

$$\text{WTP Index} = 1 - \frac{\text{Degree of public resistance to LCF}}{\text{Degree of cost premium of LCF}}$$

- WTP index **by year and by market**
- **Degree of public resistance:** % of negative views on media and social media
- **Degree of cost premium:** LCF cost as % of normal fuel cost, adjusted for the country’s cost of living



Data sources: This report is built upon three data sources featuring different angles

Dow Jones Factiva

Media articles – all major newspapers and magazines globally

Providing country specific data

Sample size: **15,227** articles on LCF (2021 – 2024)

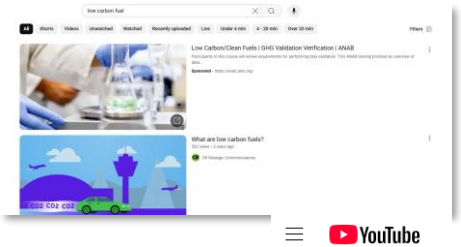
ProQuest TDM Studio

Big data containing newspapers, journals and primary sources

Automatically generated data sets

Sample size: **50,000+** articles on LCF (2021 – 2024)

YouTube



Social media comments – on videos of LCF / climate related content

Capturing the voices of the general public

Sample size: **63,701** comments on LCF-related videos (2021 – 2024)

All sources cover the contents of English and local languages

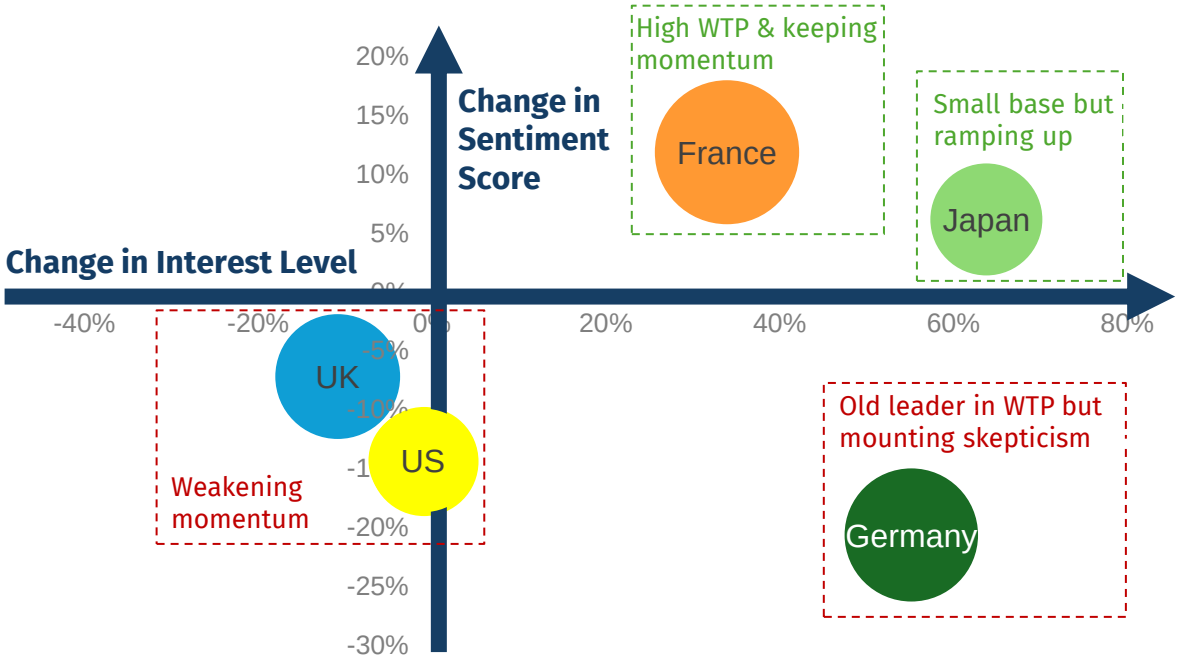
Section 0

Executive Summary

A snapshot: Divergent trends globally

Overview

Public discussions on LCF: WTP Index, Interest Level and Public Sentiment



Key metrics

Size of bubble: WTP index 2024
1 – (% neg. views / LCF cost premium), Normalized value for comparison

Interest index, change '24 vs '22
articles on LCF / total # news articles

Sentiment score, change '24 vs '22
High score = More positive views on low-carbon fuel

Executive Summary (1/3)

1 WTP is influenced by perceived sum of "direct" AND "indirect" benefits of LCF policies, as interpreted from media/ social media texts. Public does not simply view LCF as paying extra price for the pure purpose of decarbonization (direct benefits); Countries also consider additional economic values brought by LCF policies (indirect benefits).

1.1 On media and social media, discussions on LCF are largely in the context of investment opportunities, target feasibility and policy incentives. In markets where **LCF policy is incorporated within a broader industrial strategy** and believed to bring business and employment, LCF is more likely to enjoy favorable momentum and public support.

1.2 Inflation and energy security are not at the center of LCF discussions. **High inflation DOES NOT appear to necessarily lead to public resistance towards LCF**. In times of high energy costs, the price gap between LCF and normal fuel is smaller and it may be easier for business to pass on incremental costs to end-consumers.

2 Softened policy drive: In major Western markets (US, UK, Germany), public support and WTP for LCF peaked in 2022, and started to turn weak afterwards along with the overall climate movement.

2.1 When the Ukraine War disrupted global oil and gas supply in 2022, public concerns on energy security and government incentives on green energy investment pushed sentiment on LCF to the highest level.

2.2 However, when mandates like ReFuelEU Aviation policy came into execution, the industry experienced feasibility challenges – feedstock competition, scale-up challenge and high costs. As a result, industry skepticism on LCF target built up in 2023-2024.

2.3 Business sectors had an increasing desire for policy support amid implementation and cost challenges. However, after policy peak in 2022, the follow-up support was lacking

2.4 Growing public awareness about LCF may NOT result in a higher WTP. LCF, compared to other carbon reduction levers, is still a niche topic in public discussions today, resulting in low consumer awareness of its costs and decarbonation efficiency. Media coverage on LCF has been increasing but there are also increasing suspicions on environmental impact vs cost implications.

Executive Summary (2/3)

3 **Asia rise: While the West witnessed rising critics in 2023-24, major Asia markets (Japan, China) are increasing their interests and support in LCF, despite a low base.** Two reasons contribute to the "Asia rise":

- **3.1** Incremental transition: Japan's LCF strategy is centered on ammonia and hydrogen and built upon its existing tech strengths. Japan's approach and LCF target is seen as pragmatic vs. Europe's drastic transition plan.
- **3.2** Industrial policies: Japan and China adopt green policies to guide its industry upgrade, creating new business opportunities for their companies and expanding overseas. E.g. Japan supports ammonia companies to expand to Southeast Asia (AZEC initiative).

4 **Uneven burden:** Within EU, **France and Germany show divergent WTP trends – France is increasing support for SAF while Germany is increasingly skeptical.** The difference is shaped partly by differing industrial structures, which are impacted unequally in energy transition.

- **4.1** Viable business model: France, home to Airbus, has a sizeable aviation sector (~4% of France GDP) and a complete industry ecosystem to create business opportunities from SAF transition. E.g. Airbus launched SAF "Book and Claim" system in March 2025, driving public sentiment on LCF to a high level. However, in Germany, airlines are pure cost-takers and more resistant to SAF rules.
- **4.2** Supply capability: France has a agriculture sector c.2X the size of Germany's and cheap electricity from nuclear, making local LCF production feasible. Currently France has larger SAF productive capacity than Germany.
- **4.3** Policy prudence: Despite aggressive EU SAF target, the French government has been more prudent in implementing energy transition since 2018 Yellow Vest Protest.
- **4.4** The divergent WTP trends echo the recent Parliament election result in France and Germany – French "green party" EELV increased seated (16 in '22 → 28 in '24); whilst German "green party" Alliance 90/The Greens lost seats (118 in '21 → 85 in '25).

Executive Summary (3/3)

5 Business implications: Feasible targets, sustained policy incentives, and public communications on derived economic opportunities are the key ingredients of high WTP. WTP trends differ by country. LCF players shall monitor key indicators such as

- **5.1** Political agenda: Motivation of the business sector has to be sustained with continued policy support. At times when conservative parties gain votes, companies would expect a low time on ESG related agenda and skepticism would build up.
- **5.2** Target accomplishment level: Over-aggressive policy targets could trigger public backlashes. Tracking current accomplishment level given hints for future public sentiment.
- **5.3** Public awareness of LCF: Today LCF still has low awareness among end-consumers and public discussion is mainly driven by business opportunities. As its consumer awareness grows, inflation and fuel cost level could play a bigger role in impacting WTP in the future.
- **5.4** LCF cost changes: Reasonable production costs, depending on feedstock price and technology iteration, directly impact business confidence and rollout feasibility.

Section 1

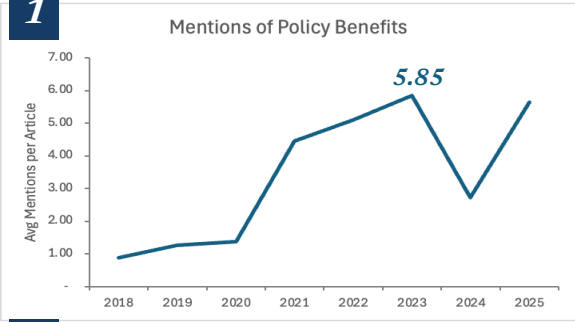
1

WTP Index and Trends by Market

Public discussion on LCF goes beyond carbon & costs – business opportunity is also important

- Word frequency analysis for the U.S. and the U.K. shows that inflation, policy benefits, energy security and supply chain are key topics when sentiment peaked

1



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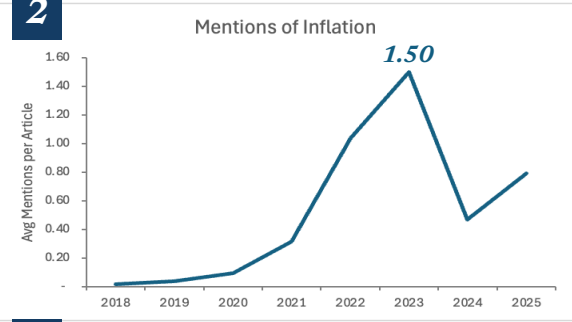

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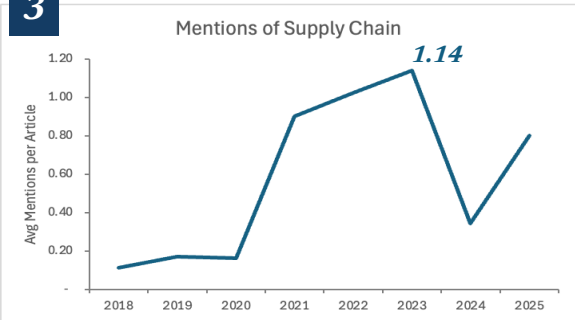

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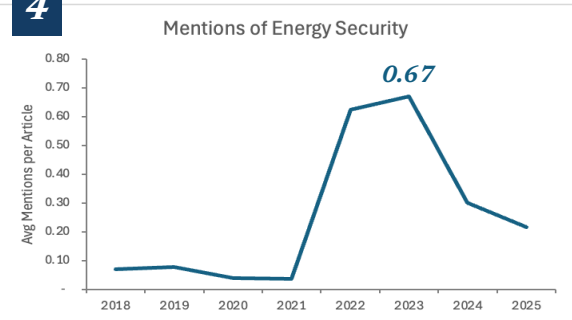
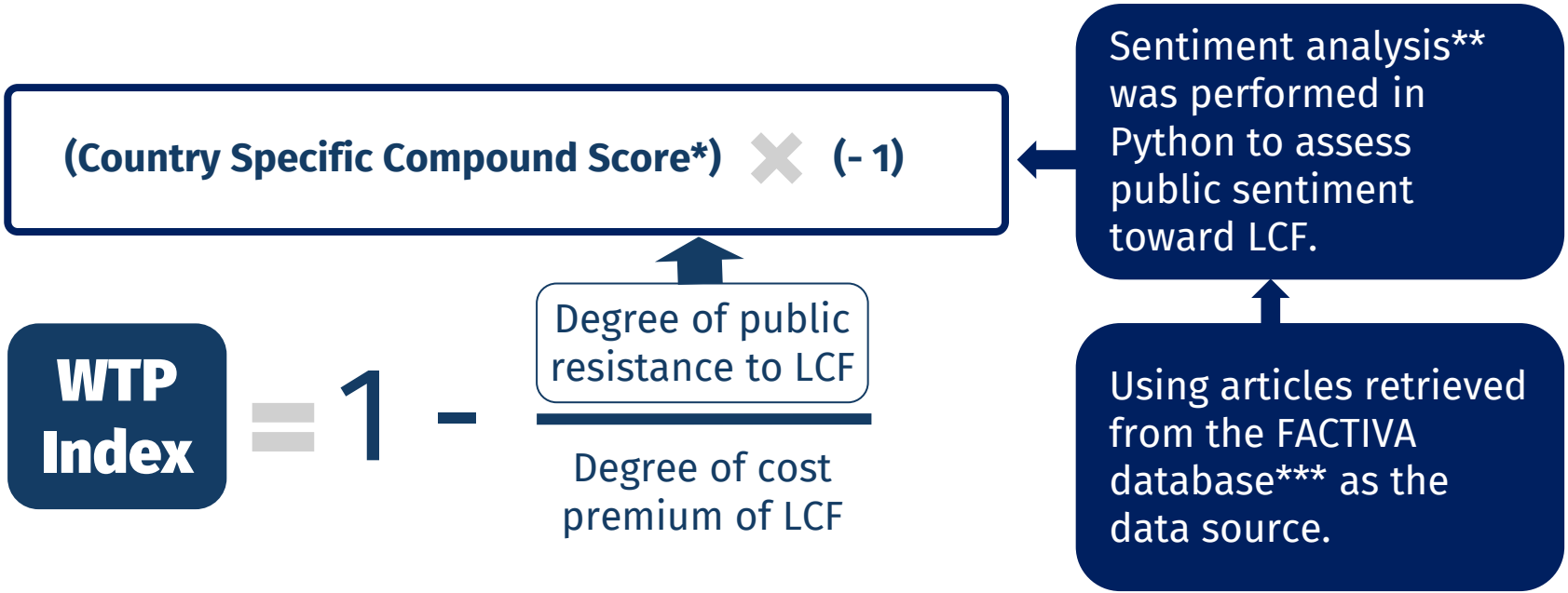


Observations

- **Inflation** is frequently discussed during periods of peak sentiment, indicating that it is not necessarily associated with negative sentiment
- **Policy benefits** are frequently discussed, peaking from 2021 to 2023
- **Energy security** became a major topic after the Ukraine crisis, but declined in 2024.
- **Supply chain** is frequently mentioned from 2021 to 2023

* Policy benefits include keywords: *incentive(s), subsidy(ies), tax credit(s), tax benefit(s), Inflation Reduction Act (IRA)*
* Energy security include keywords: *energy security, energy crisis, Ukraine*

Methodology: WTP Index reflects public sentiment toward LCF



*Sentiment Score: In this study, this shows a normalized, weighted composite sentiment score (Compound Score) ranging from -1 (most negative) to +1 (most positive). See appendix I. for details.

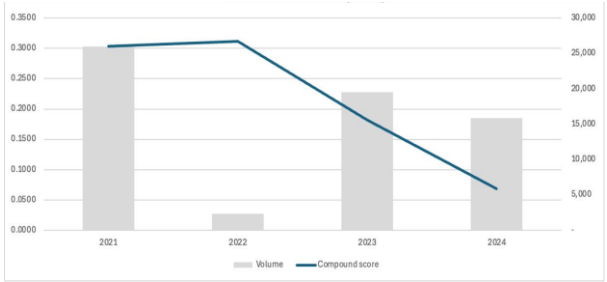
** For more information on the method of the country specific sentiment analysis, see Appendix II.

*** To calculate the country-specific WTP index, we use only articles published in FACTIVA as the data source for public sentiment. While FACTIVA is a news aggregator that compiles content from over 30,000 sources in 32 languages, it is important to note that the sources may be biased toward certain countries' news outlets.

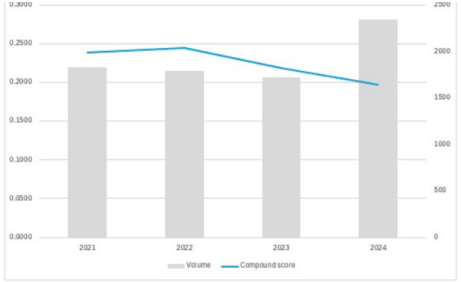
Globally, Public sentiment on “Low-carbon fuel” shows a turning points in 2022

Public sentiment, “Low-carbon fuel”, Global

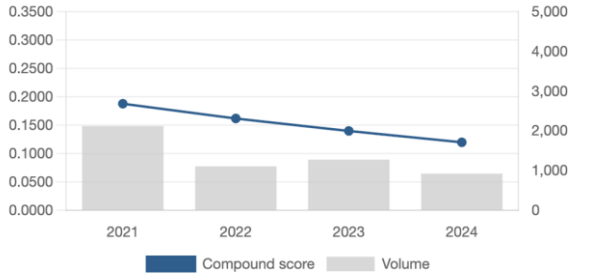
YouTube



Factiva



TDM studio



TDM studio

Year	Overall Compound	Article Count
2021	0.188	2,122
2022	0.162	1,108
2023	0.140	1,278
2024	0.120	923

YouTube

Year	Compound score	Volume
2024	0.0685	15,855
2023	0.1823	19,485
2022	0.3112	2,363
2021	0.3035	25,998

Figure 1: LCFS Credits Issued (Millions per Year)

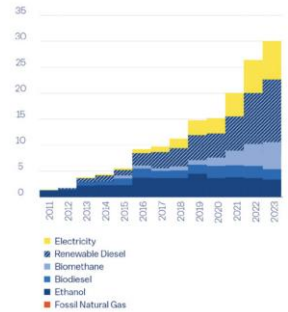
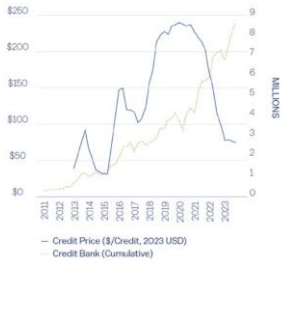


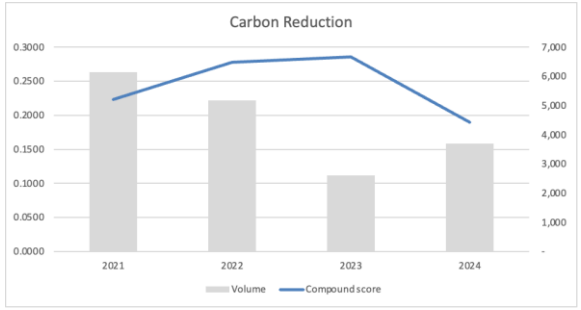
Figure 2: LCFS Credits Prices and Net LCFS Credit Bank



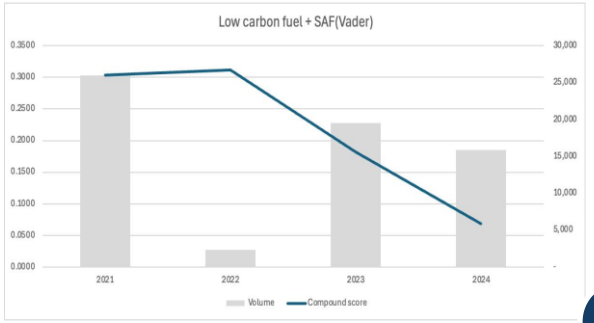
- YouTube, Factiva and TDM studio all show similar trend of a decreasing sentiment result during 2021 - 2024
- 2022 - 2023 dip: Energy crisis response (2022); Stagnating or uncertain mandates, e.g. EPA slash (2023), BP scale back transition goals (2023); Reduced government support in 2023 (Sweden from 30% - 6%)
- Our sentiment result aligns with California’s LCFS credit price crash.

That correlates to a wider trend of the weakening voice on climate agenda after 2022

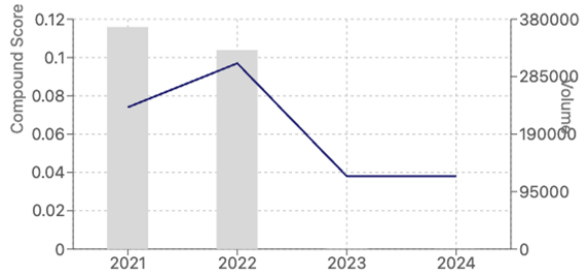
YouTube - Carbon Reduction



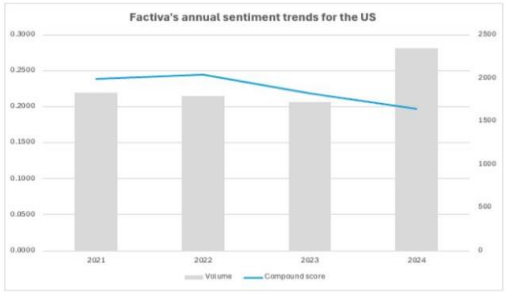
YouTube - Low Carbon Fuel



TDM studio - Carbon Reduction



Factiva - Low Carbon Fuel



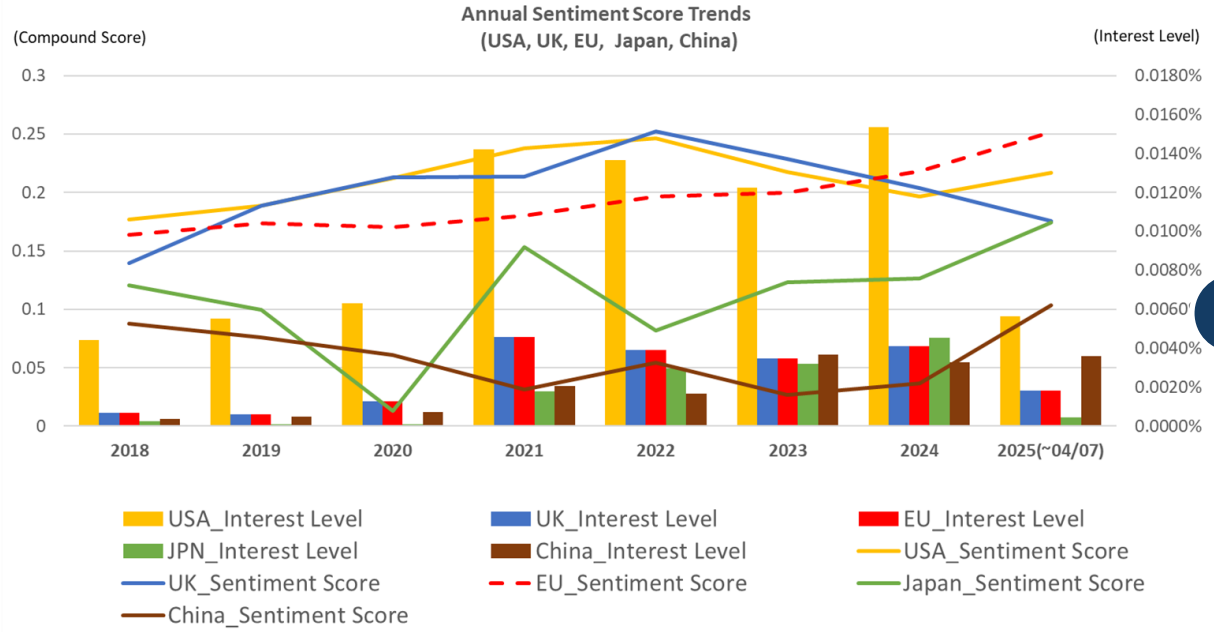
Observations

- Various channels present similar trends in Carbon Reduction sentiment
- There appear to be a turning point for carbon reduction in 2022 - 2023, before plateauing in 2024. This potentially leads the low carbon fuel turning point
- Due to TDM studio system constraint, there are less sample to show the trend from 2023 - 2024. But the 2022 - 2023 drop is still significant and aligns with the results from other platforms.

[Factiva]

Country specific sentiment trends - USA, UK, EU, Japan, China

- Sentiment toward low-carbon fuels varies by country and region.
- In particular, **Asia** exhibits a different trend compared to the **western countries**.



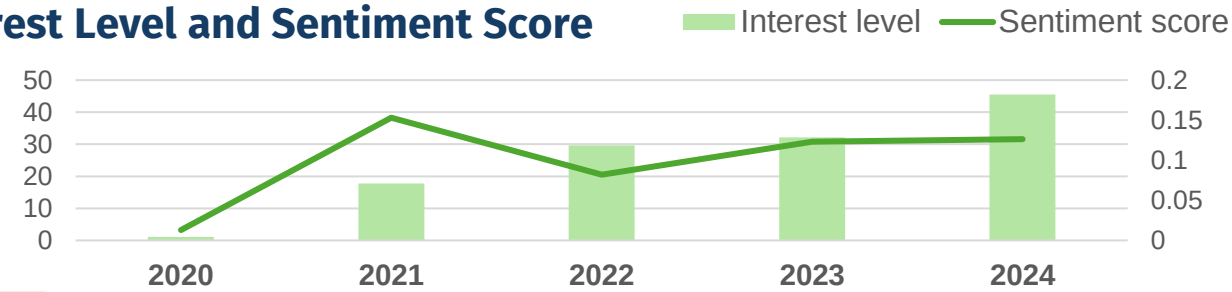
Observations

- **Western countries** (USA, UK, and EU) show a **higher trend** than **Asian countries** (Japan and China).
- The interest level* in the USA is significantly higher **during the Biden administration** (2021–2024).
- While the compound scores for the **USA and UK** have **declined since 2022**, **Asian** countries show an **upward trend** through 2025.

* Interest level: Percentage of articles related to LCF among all articles from the country or region recorded in FACTIVA.

Case study: Japan shows rising interests and support on LCF as ammonia/ hydrogen is integrated into its national industrial strategy

Japan: LCF Interest Level and Sentiment Score



Interest Level
(# articles on LCF per 1M news articles)

Sentiment Score
(Higher score = Positive views)

2022: critics on greenwashing

- Japan launched LCF plan in May '22 – Centered on hydrogen & ammonia
- Criticized by G7 and domestic media – keeping coal-fired power plant, "blue hydrogen" from natural gas, etc.

2023-2024: Improving acceptance

Public communication by government and leading corporations:

- Gov't launched mass marketing campaigns
- Private companies advertised on TV, YouTube and outdoor

Clear rationale explained to public:

- Leverage existing tech advantage in co-firing power plant
- Develop global leadership in hydrogen
- Economically viable

Support overseas expansion:

- 2023: Asia Zero Emission Community (AZEC) to promote hydrogen/ammonia to Southeast Asia
- Support Japanese companies to win overseas projects

Strategic funding:

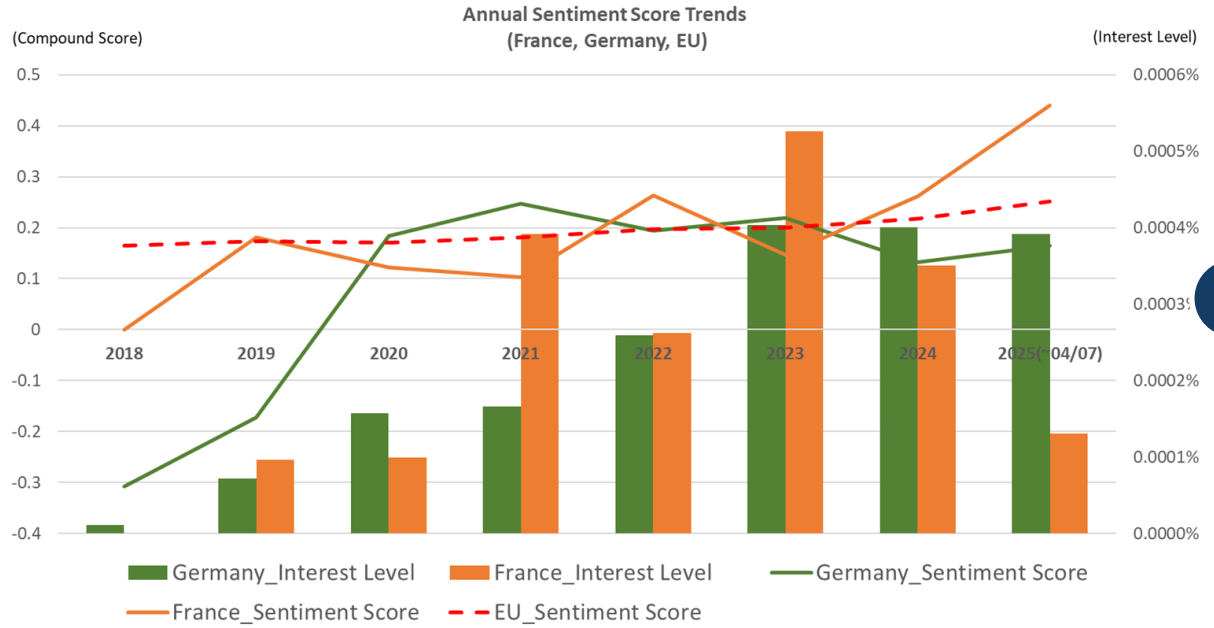
- 30-year Green Transformation (GX) Bond issued to fund hydrogen/ ammonia subsidies
- Cost premium not directly charged on electricity bill

Source: desktop research, expert interviews

[Factiva]

Country specific sentiment trends - France, Germany, EU

- Differences in **economic structure (the strength of the agricultural sector)** and **political environment** drive each country's sentiment score.



Observations

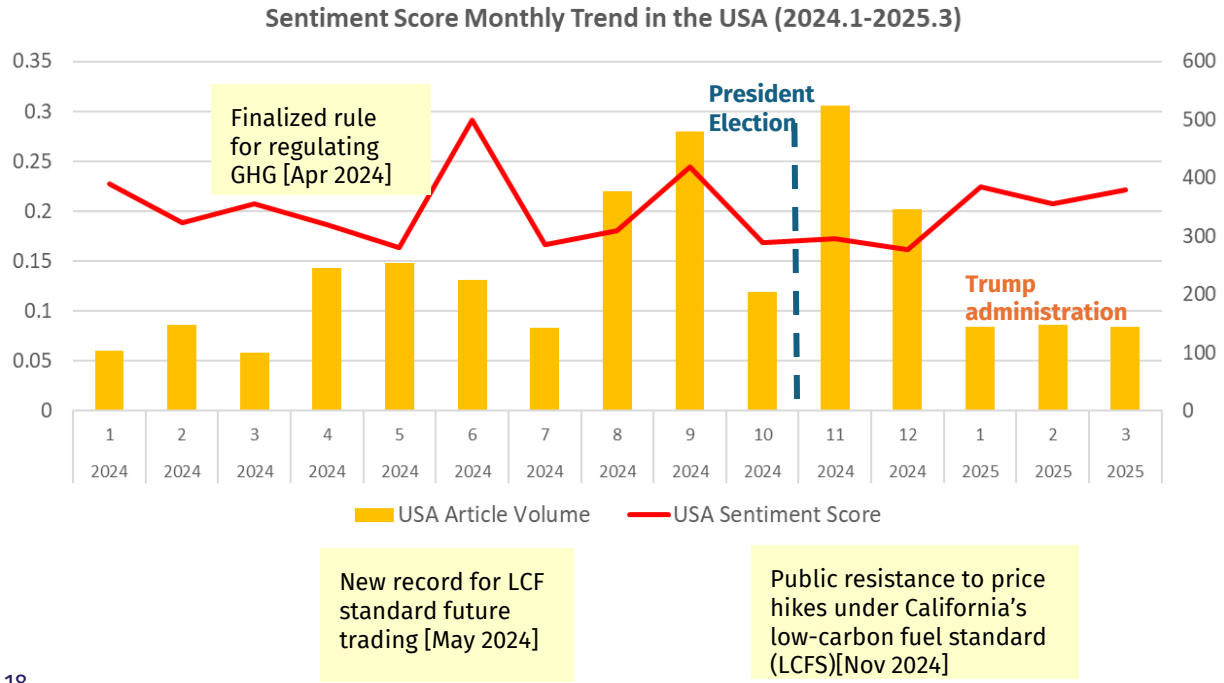
- Each country in The EU has its own distinct trajectory in the behind.
- **Germany** experienced a **shift toward more conservative political positions**, while **France** saw increased support for both far-right and green parties, indicating a **broader trend toward political polarization**.
- The strength of each country's **agricultural sector** influences the scores.

*Back data articles are in English for the EU. For Germany and France, they are in English and the respective national language.

[Factiva]

Monthly sentiment trends - USA (2024-)

- In the USA, public attitudes are much more influenced by the federal **administration's policies** than in other countries.

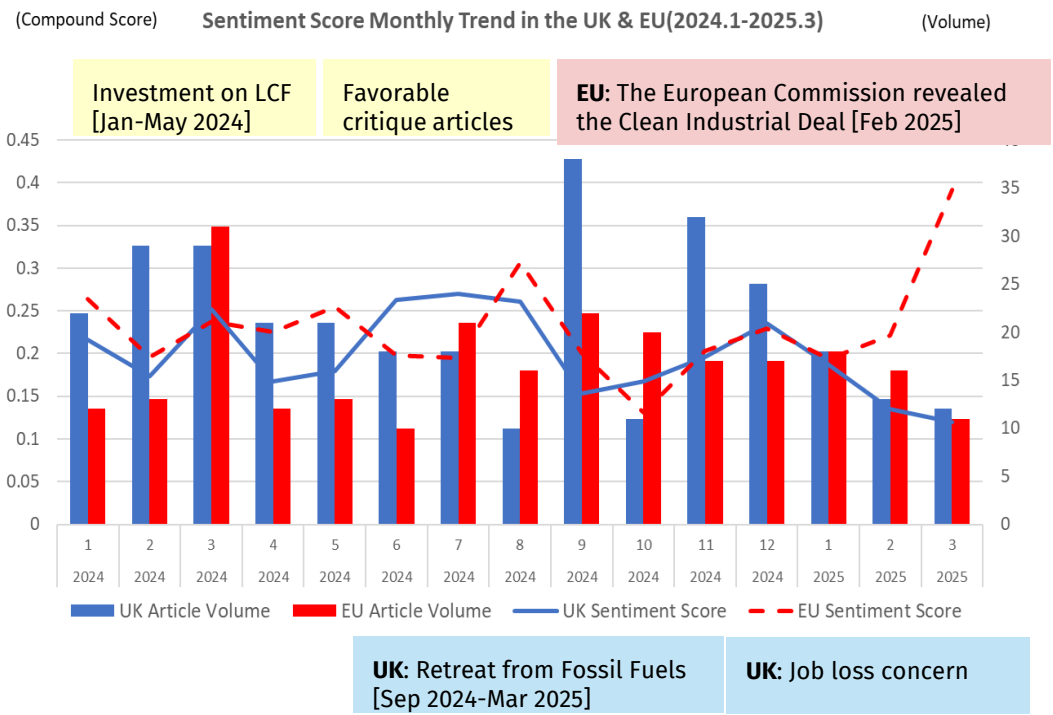


- In April 2024, **new GHG rules under the Biden administration boosted attention to LCF**. Trading surged (record-high futures in May), pushing up sentiment scores.
- **After the November 2024 election**, backlash grew over fossil fuel price hikes under California's LCFS.
- **Since the Trump administration** began in January 2025, LCF media coverage has declined, indicating **the decrease in market interest**. On the other hand, regional actions as planned, such as in NY and California, push up the score.

[Factiva]

Monthly sentiment trends - UK, EU (2024-)

- Without **policy support** for job creation through LCF and measures to mitigate concerns about job losses associated with the phase-out of fossil fuels, the score will



- **Positive LCF propaganda** (editorials, op-eds) is more active in the UK and EU media.
- Since the fall of 2024, the closure of refineries and other **decarbonization measures** have led to tangible **job losses**, causing the score to decline.
- In the **EU**, the announcement of **the Clean Industrial Deal** in February 2025 led to a sharp increase in the score. In contrast, in the **UK**, **ongoing concerns over job losses** caused the score to continue declining, resulting in a graph that opened wide like a V-shaped split opening sideways.

Methodology: WTP Index reflects public tolerance on different levels of fuel costs by market

WTP Index = 1 − Degree of public resistance to LCF / Degree of cost premium of LCF

Note: The LCF price is based on cost modeling, not actual market prices.

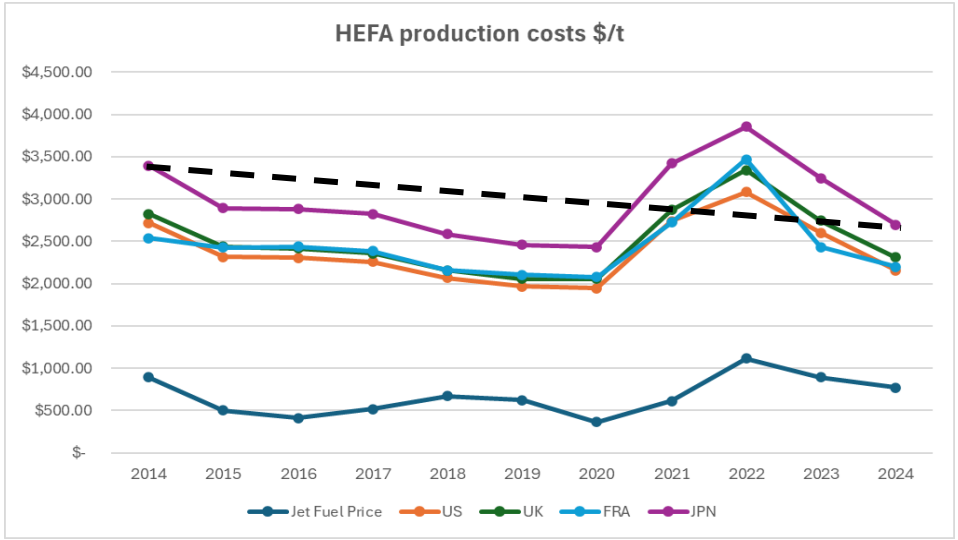
The cost premium (the difference between LCF and fossil fuel prices)

LCF price [$/t] − **fossil fuel price [$/t]**

Adj. factor for cost of living (GDP per capita PPP [$])

Cost of living /consumer purchasing power in each country

We modeled the levelized production cost of commonly used SAF products – HEFA costs used WTP Index calculation



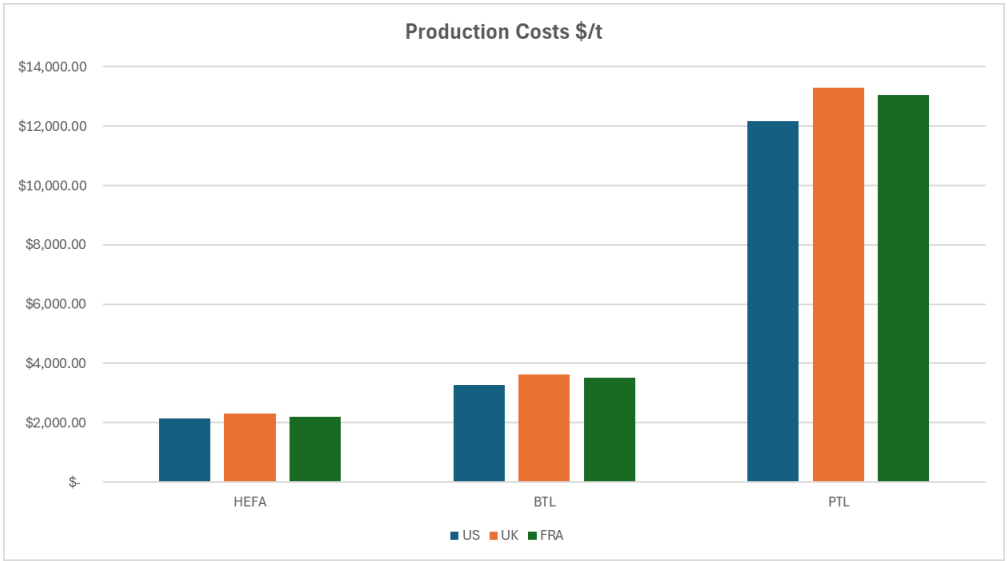
Cost modeling approach in APPENDIX III

- Countries with feedstock and domestic production have a cost advantage
- HEFA costs reflect feedstock price volatility - soybean oil
- Structural downward trend in production costs

US: $2,159 **UK: $2,309** **FRA: $2,201** **JPN: $2,690**

Back-up: More advanced fuels exhibit larger cross-country differences and may further widen regional gaps on WTP

Cost of advanced fuels NOT reflected in WTP Index calculation



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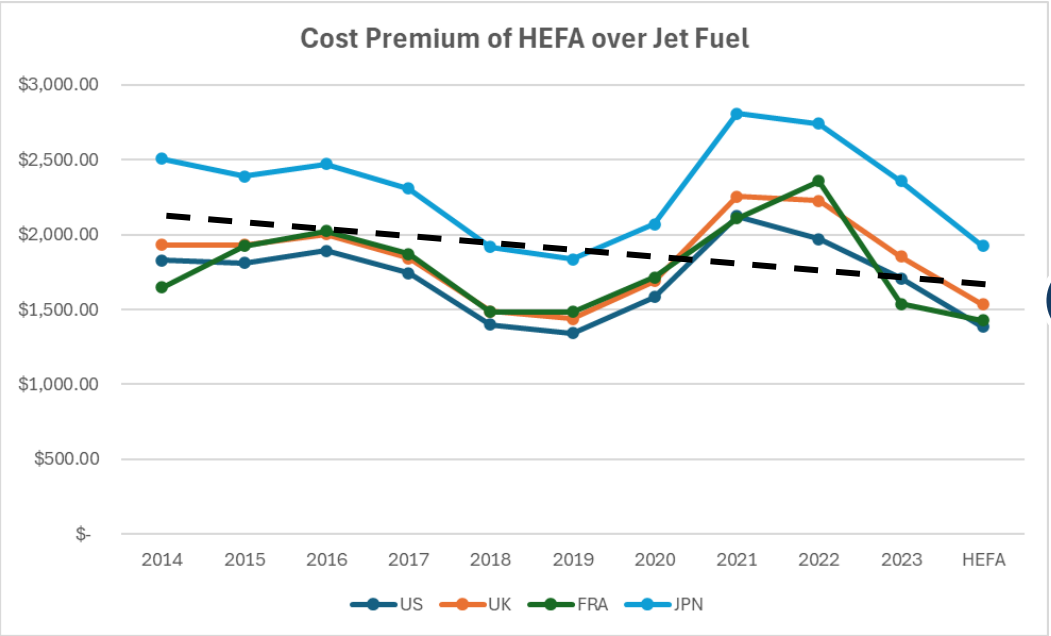
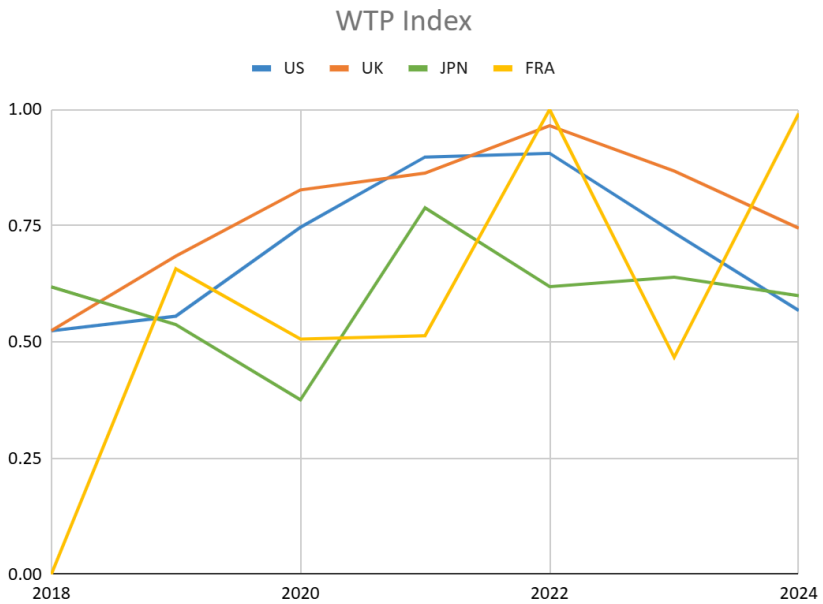
- More advanced fuels exhibit larger cross-country differences due to varying electricity prices and cost of capital
- HEFA is 80% of SAF production

The cost premium of SAF over conventional jet fuel is adjusted for the cost of living by country



- Japan exhibits higher premia
- Maturing market with decreasing cost of capital
- Higher capex but lower OpEx
- Feedstock prices recovered from Covid shock
- Plateau in cost reductions

Modeled result: WTP Index by market



Observations

- It essentially aligns with the **sentiment score** from Factiva, but the WTP index also takes into account the **cost premium variation across countries**.
- Overall, the **US, UK, and France increased their WTP** and **reached the highest levels in 2022**, while **Japan saw a drop** that year.
- Since 2023, **WTP in the US and UK has declined**, but **France recovered** and reached a new peak. **Japan has remained at the same level**.

2

Drivers That Influence Willingness-to-Pay

Feasible targets, sustained policy incentives, and derived economic opportunities are the key ingredients of high WTP

- Drivers were selected based on the **literature on WTP** and **our own hypothesis**
- At the global level, **policy-related drivers** - such as **climate pledges, regulations, standards, and targets for LCF** - and economic factors like the **inflation rate** show moderate correlation with the WTP index."
- **Awareness of climate change** shows a weak correlation with WTP.

Driver Category	Driver	Indicator	Correlation Coefficient (r) with WTP index (pooled)
Awareness & Perception	Public interests in LCF	Relative frequency of Google searches [index]	0.39
	Awareness of Climate Change	Awareness Survey about Climate Change [%]	-0.18
Policy & Regulation	**Regulations, Standards & Targets**	**Targeted share of LCF [%]**	**0.39**
	Climate Pledges	**GHG emissions reduction target on NDC etc. [%]**	**0.52**
	Government Investment in LCF	Pledged government investment in LCF [$]	0.28
Political Environment	Political Party Representation	Share of pro-green parties' seats [%]	0.29
	Lobbying	The number of newly established legislations [number]	0.02
Economic Conditions	Economic Growth	GDP per capita growth [%]	0.17
	Inflation Rate	**Inflation Rate [%]**	**0.46**
	Oil Price	Regional market oil price [$/barrel]	0.35
	Natural Gas Price	Regional market natural gas price [$/MMBtu]	0.37
	Electricity Price	Retail electricity price [$/MWh]	0.26

Methodology: Driver Analysis

- **Step 1:** Normalize the values for each driver (X: explanatory variable) using Z-score standardization based on a statistical method.

$$Z_i = \frac{X_i\,(original\ value) - \mu\,(mean\ of\ X)}{\sigma\,(standard\ deviation)}$$

  - Note: For variables with multiple data sources, use the average (or weighted average) of the Z-scores. For years with missing data, use interpolation to estimate the values.

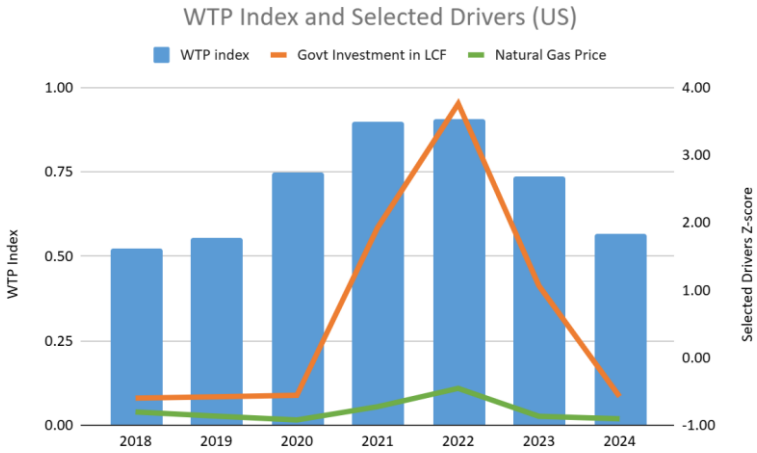
- **Step 2:** Analyze the relationship between drivers and the WTP index by comparing how both have changed over time and by calculating the correlation coefficient (r).

Beyond global level, regional differences in drivers worth noticing

- The drivers that correlate with WTP vary significantly across countries, reflecting **each country's unique context**.
- **Government investment in LCF** shows a relatively strong correlation with WTP in the **US, UK, and Japan**.
- Economic indicators such as **inflation rates in the US and UK** also show similar trends with WTP.
- Energy prices -**oil and natural gas** - have a positive correlation with WTP in most countries.
- Political drivers, such as **party representation**, have varying impacts depending on the country.

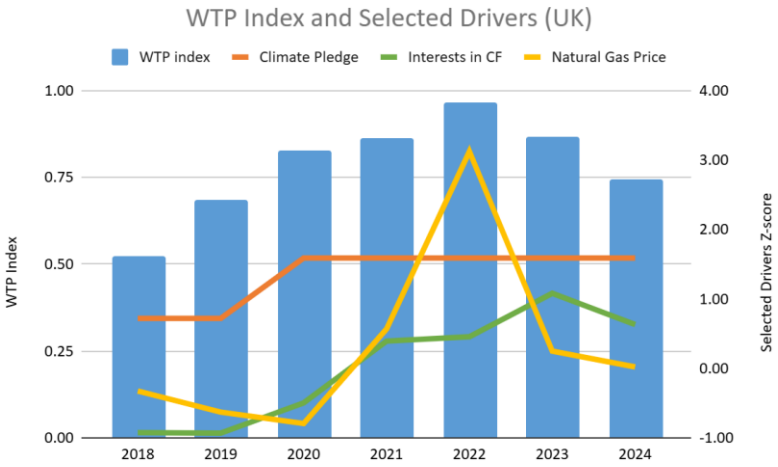
Driver	Poole	US	UK	Japan	Franc
Interest in LCF (Google Search)	0.39	0.23	0.70	0.31	0.53
Awareness of Climate Change	-0.18	-0.12	0.97	-0.13	-0.33
Regulations, Standards & Targets	0.39	0.36	0.62	0.15	0.58
Climate Pledges	0.52	0.56	0.84	0.65	0.55
Government Investment in LCF	0.28	0.86	0.64	0.74	0.14
Political Party Representation	0.29	-0.48	-0.59	-0.13	0.56
The number of pro-green legislation	0.02	0.13	-0.28	0.38	-0.29
Economic Growth (GDP growth)	0.17	0.16	0.12	0.91	0.07
Inflation Rate	0.46	0.72	0.60	0.15	0.29
Oil Price	0.35	0.32	0.34	0.59	0.44
Natural Gas Price	0.37	0.65	0.65	0.36	0.52
Electricity Price	0.26	0.20	0.38	0.16	0.30

In US, public investment in LCF plays an important role



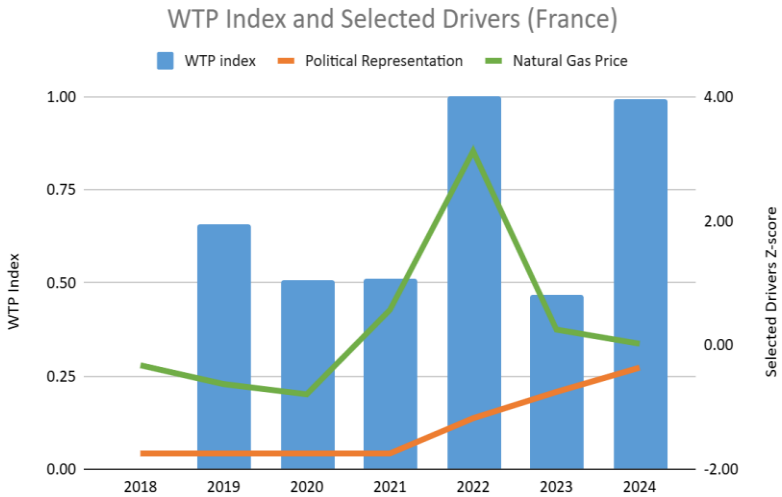
- **Government investment in LCF shows the strongest correlation with the WTP index (r = 0.86)**. The index rose significantly in the years when large budgets were pledged to support hydrogen and SAF production - specifically under the **Infrastructure Investment and Jobs Act (IIJA) in 2021** and the **Inflation Reduction Act (IRA) in 2022**.
- **Natural gas prices also show a relatively strong correlation with WTP (r = 0.65)**, possibly reflecting increased interest in alternative fuels as fossil fuel costs rise.
- **Climate pledges have a moderate correlation with WTP (r = 0.56)**, likely influenced by the ambitious net-zero targets announced in 2021, which may have boosted public support.
- Political indicators, such as **pro-green party (Democratic) representation, show a negative correlation with WTP (r = -0.48)**, possibly reflecting the lower relative emphasis on climate and energy within the broader political agenda.

In UK, Climate policies and rising public awareness plays a key role



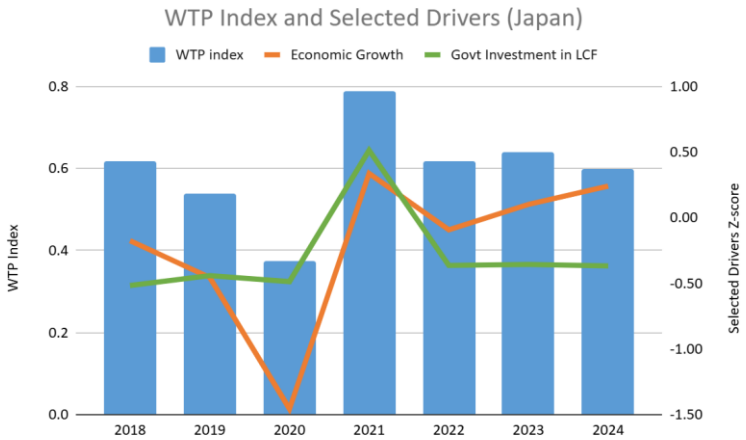
- **Awareness shows the strongest correlation with the WTP index (r = 0.97)**, unlike in the other countries**.**
- **Climate pledges also show a strong correlation with the WTP index (r = 0.84)**, particularly in 2019 and 2020 when the government committed to a net-zero target and passed related legislation.
- **Public interest (frequencies of google search) also shows a moderate correlation with WTP (r = 0.70)**, suggesting that growing public awareness may contribute to more positive perceptions.
- **Natural gas prices also have a relatively strong correlation with WTP (r = 0.65)**, likely reflecting increased interest in alternative fuels as fossil fuel costs rise.
- **Policy targets shows a moderate correlation with WTP (r = 0.62)**, possibly signaling to the market or consumers the potential of the technology.

In France, the policy pledges and political environment play a greater role



- **Policy targets for LCF shows the strongest correlation with the WTP index among all variables (r = 0.58).**
- Unlike in other market, **political representation of pro-green parties has a moderate correlation with the WTP index (r = 0.56)**. The rise in parties like Europe Écologie – Les Verts (EELV) may have influenced public perception.
- **Climate pledges also show moderate correlations (r = 0.55)**, suggesting that France's policy and political initiatives may have contributed to more positive public views.
- **Natural gas prices show a positive correlation (r = 0.52)**, possibly reflecting increased public support for alternative energy sources like LCF.

In Japan, an economic confidence and public support in LCF boosted public acceptance



- **Economic growth (GDP growth rate) shows a strong correlation with WTP (r = 0.91)**, suggesting that economic growth may boost public confidence in clean energy investment.
- **Government investment in LCF is also positively correlated with WTP (r = 0.74)**, particularly during major pledges like the **Green Innovation Fund in 2021**, which aimed to support Japanese industries and capture economic opportunities in the Asian market.
- **Climate pledges also correlate with WTP (r = 0.65),** especially after the government legislated the net-zero goal in 2021.
- **Oil prices show a moderate correlation (r = 0.59)**, possibly because high fossil fuel prices increase interest in alternatives for cost and energy security reasons.
- **Public interest, measured by the share of articles on LCF, has a moderate correlation (r = 0.57)**. The drop in 2022 may reflect a rise in critical media coverage of Japan's hydrogen and ammonia policies, which later declined.

Back-up: Increasing Awareness may not necessarily bring higher WTP

- **Increased Skepticism**
  - Consumer skepticism increases with awareness. As consumers become more informed, they demand more transparency, traceability, and proof that their money contributes to real emissions reductions and not toward green-washing and vague climate claims.
- **Perceived Impact is Minimal**
  - As consumers learn more, they often realize their individual contributions feel negligible.

A research by the Royal Aeronautical Society (RAeS) into public attitudes on decarbonizing aviation reveals that most respondents are concerned about the impacts of climate change, but only 38% of respondents were willing to pay more to cut carbon emissions from their flights.

- We can observe in this study that while increased awareness of climate change generally leads to greater support for sustainable initiatives, factors like inefficiency and economic constraints can influence individuals' willingness to pay for options like SAF.

Another Survey kind of research by Thomas Curry on climate change mitigation discussed carbon capture, but the findings can still be applied to the idea that even among climate-concerned individuals, greater awareness of technical details can lead to hesitation, due to concerns about effectiveness, safety, or cost.

- An experiment within the survey shows that a large portion of the public supports investment in renewable energy technologies, but that support decreases when cost information for all climate mitigation technologies is provided.

- Royal Aeronautical Society. (2025). Public attitudes to the decarbonization of aviation.
- Curry, T. (2004). Public Awareness of Carbon Capture and Storage (MIT Master's Thesis).

Business implications: Public support and WTP is dynamic – LCF players shall watch out for a few key indicators

Regional difference	• Recent WTP trends differ by market, driven by each country's policy approach, industrial structure and supply-demand position. • The recent rising momentum in Asia markets worth attention.
Political agenda	• Motivation of the business sector has to be sustained with continued policy support. • At times when conservative parties gain votes, companies would expect a low time on ESG related agenda and skepticism would build up.
Target accomplishment level	• Over-aggressive policy targets could trigger public backlashes. • Tracking current accomplishment level given hints for future public sentiment.
Public awareness of LCF	• Today LCF still has low awareness among end-consumers. • As its consumer awareness grows, inflation and fuel cost level could play a bigger role in impacting WTP in the future.
LCF cost changes	• Reasonable production costs, depending on feedstock price and technology iteration, directly impact business confidence and rollout feasibility. **T** • Tech evolvement may widen regional price gap, and therefore local WTP by market.

APPENDIX

APPENDIX I: Compound Score in Sentiment Analysis

- The compound score, which is used as the “sentiment score” in this study, is a normalized, weighted composite sentiment score ranging from -1 (most negative) to +1 (most positive)
- It is calculated by summing valence scores of words and adjusting them based on intensity modifiers, negations, and punctuation, then normalized using a scaling factor

$$\text{compound} = \frac{\sum_s}{\sqrt{\sum_s^2 + \alpha}}$$

(α = 15)

APPENDIX II: Methodology Overview (Country-Specific Compound Scores)

Step 1: Article Collection via Factiva

- Use Factiva (one of the largest news aggregators, with over 30,000 sources in 32 languages, including major national and international publications, local news, newswires, and business sources).
- Search using the term "low carbon fuel" (or its translations in Japanese, French, or German) while specifying the country or region of interest.
- Download all articles published during the target period.

Step 2: Sentiment Analysis Using NLTK and VADER (Python)

- Use Python NLTK package with the VADER sentiment analysis tool.
- Calculate a sentiment score for each line of the article, then compute the average score for the entire article.
- After scoring all downloaded articles, calculate monthly or yearly averages depending on the required level of analysis granularity.

APPENDIX III: Data sources for sentiment assessment -- Media covered in Factiva (1/2)

4 Wheel Drive & Sport Utility, 4Wheel & Off-Road, 4Wheel Drive, 5.0 Mustang & Super Fords, 8-Lug Diesel Truck, ABA Bank Security & Fraud Prevention, ABA Banking Journal, ABC News Now, ABC News, The Abilene Reporter-News (Texas, U.S.), Absolute Return, ACCESSWIRE, Accounting Department Management Report, Accounting Office Management & Administration Report, Accounting Today Online (U.S.), Ad Age Global, Adirondack Enterprise (N.Y.), Advance of Bucks County (Newtown, Pennsylvania, U.S.), Advanced Materials & Composites News, Advertising Age (U.S.), Advertising Age's Creativity, Adweek (U.S.), Adweek Midwest Edition, Adweek New England Advertising Week, ADWEEK Southeast, Adweek Southwest Edition, ADWEEK Western Edition, AFP Exchange (Abstracts), African American Review (Abstracts), Aftermarket, BusinessWorld, Agency Sales Magazine, Agent's Sales Journal, AgExporter, Agri-Pulse.com, Agricultural Chemical News (Abstracts), Agweek (Tribune Content Agency) (North Dakota, U.S.), AIA Update, aiCIO, AIDS Treatment News, AIDS Vaccine Week (U.S.), Air Force Comptroller, Air Force Law Review, The Air Force Magazine (Abstracts) (U.S.), Air Guide for the Frequent Flyer, Air Safety Week, Aircraft Alert (U.S.), Airman, Airport Business, Airport Security Report, AJHO, Akron News Reporter (Colorado, U.S.), Alamogordo Daily News (New Mexico, U.S.), Alamogordo Daily News Online (New Mexico, U.S.),Alaska (Abstracts) (U.S.),Alaska Business Monthly (U.S.),Alaska Journal of Commerce (Abstracts) (U.S.),Alaska Journal of Commerce (Tribune Content Agency), All Hands
Allegheny Business News (Pa.), The Allentown Morning Call (Pennsylvania, U.S), Allure, Alpena News (Mich.), Ambler Gazette (Pennsylvania, U.S.), American Agent & Broker, American Baby (Abstracts), American Banker (U.S.), American Banker Magazine, American Banker Online, The American Bankruptcy Law Journal, American Behavioral Scientist (Abstracts), American Business Law Journal (Abstracts), American Business Review, American Ceramic Society Bulletin (Abstracts), American City & County, American Demographics
American Druggist, American Enterprise, American Forests, American Gunsmith, American Handgunner, American Health Line, American Hunter (Abstracts), American Indian Culture & Research Journal (Abstracts), American Journal of Chinese Medicine, American Journal of Health Studies, American Journal of Law & Medicine, American Journal of Nursing (Abstracts), American Journal of Physics (Abstracts)
American Lawyer, American Libraries (Abstracts), American Literature (Abstracts), American Paint & Coatings Journal (Abstracts)
American Politics Research (Abstracts), American Public Media: Marketplace AM, American Public Media: Marketplace Money, American Public Media: Marketplace PM, American Public Media: Speaking of Faith, American Public Media: Weekend America, American Quarterly (Abstracts), American Record Guide, American Rehabilitation (Abstracts), American Review of Public Administration (Abstracts)
American Rifleman (Abstracts), American Studies International, American Theatre, American Visions, Analog Planet (U.S.), Anchorage Daily News (Alaska, U.S.), AnchorDesk from ZDWire, The Anderson Independent-Mail (South Carolina, U.S.)

APPENDIX III: Data sources for sentiment assessment -- Media covered in Factiva (2/2)

The Anderson Independent-Mail Online (South Carolina, U.S.), Annals of the American Academy of Political & Social Science (Abstracts)
Annals of the Association of American Geographers (Abstracts), ANSOM, Antelope Valley Press (Calif.), Anti-Racism Daily (U.S.)
Antitrust Litigation Reporter, AP Broadcast (Available through Third Party Subscription Services), AP News Digests and Advisories (Available through Third Party Subscription Services), AP Planner (U.S.), AP Washington Daybook (Available through Third Party Subscription Services), APCJ Fax News, API Account, Apollo, App.com (Asbury Park, New Jersey, U.S.), Appeal-Democrat (Tribune Content Agency) (Marysville, California, U.S.), Applied Clinical Trials, Argus Courier (Petaluma, Calif.), Argus Leader (Sioux Falls, South Dakota, U.S.), Argus Leader Online (Sioux Falls, South Dakota, U.S.), Arizona Business, Arizona Capitol Times (U.S.), The Arizona Daily Star (Tuscon, Ariz.), The Arizona Daily Sun (MCT), Arizona Highways (Abstracts), The Arizona Republic (Phoenix), Arizona Trend, Arkansas Banker (Abstracts), Arkansas Business (U.S.), Arkansas Business and Economic Review, Armed Forces Comptroller (Abstracts), Armed Forces Newswire Service (U.S.), Armor, Army (Abstracts), Army Sustainment (U.S.), Art Education, Art in America, Asbestos Litigation Reporter
Asbury Park Press (New Jersey, U.S.), Ascribe News (U.S.), Asheville Citizen-Times (North Carolina, U.S.), Asheville Citizen-Times Online (North Carolina, U.S.), Asset (Abstracts), Asset Securitization Report Online (U.S.), Association Meetings, The Atlanta Journal - Constitution, The Atlantic (U.S.), The Atlantic, ATM Marketplace (U.S.), Attorney CPA, ATV Rider, Auditing: A Journal of Practice & Theory (Abstracts), Auditor's report, Auto Remarketing (U.S.), Automotive Industry Litigation Reporter, Automotive News (U.S.), Automotive Plastics, AutoWeek, Aviation Litigation Reporter, Aviation Maintenance, Aviation Today's Daily Brief, Avionics, AWSTest1, Axios (United States), AZCentral (Phoenix), Backpacker, Baggers, Baking Management, The Baltimore Banner, Baltimore Daily Record, The Baltimore Sun, Bangor Daily News (Maine, U.S.), Bank Accounting & Finance, Bank Advertising News, Bank and Lender Liability Litigation Reporter
Bank Investment Consultant, Bank Operations Bulletin, Bank Personnel News, Bank Rate Monitor (Abstracts), Bank Technology News
Bankruptcy Prospector (U.S.), Barron's, Barron's Blogs (U.S.), Barron's Online (U.S.), Basilandspice.com, Bass Player, The Battle Creek Enquirer (Michigan, U.S.), The Battle Creek Enquirer Online (Michigan, U.S.), The Beach Reporter (Hermosa Beach, California, U.S.)
The Beaufort Gazette (N.C.), Bee Culture (Abstracts), BEEF (U.S.), Beige Book, Bellingham Business Journal, Benefits Law Journal (Abstracts), BenefitsPro.com, Benzinga.com (U.S.), The Bergen Record (New Jersey, U.S.), The Bergen Record Online (New Jersey, U.S.)
Berkshire Hathaway Shareholder Letters, Berksmont News (Pottstown, Pennsylvania, U.S.), Best's Insurance News (U.S.), BidMatch
Billboard (U.S.), The Billings Gazette (Mont.) … etc. See https://proquest.libguides.com/factiva/content for more information.

APPENDIX III: Modeling of the levelized production cost of low-carbon fuel (1/3)

Model the cost per ton in USD to produce SAF across three pathways: HEFA, BTL, PTL, for four countries: US, UK, France, Japan. Integrating:

- CAPEX amortization
- OPEX and utility costs
- Feedstock and transport costs
- Hydrogen usage
- Financing assumptions (WACC-based)
- Policy neutral (but the model is structured to include policy credits)

Key Assumptions:

Annual Output of the modelled plant: 100,000 tons of SAF/yr
Lifetime: 15 yrs
Capacity factor: 90% for HEFA, 80% for BTL, 60% for PTL

Conversion Efficiency:

HEFA: improves linearly over time from 50% to 80%
BTL: 50%
PTL: 32% with detailed hydrogen and energy input modeling

Cost Components:

Feedstock cost = feedstock price * feedstock needed per ton of SAF adjusted based on yield improvement and hydrogen input needs
Feedstock price data is Soybean Oil for HEFA empirically collected per month from official sources and averaged to get a yearly figure.
For BTL, we use Lignocellulosic biomass.
Hydrogen costs are based on market prices as empirically collected for every market.

APPENDIX III: Modeling of levelized production cost of low-carbon fuel (2/3)

For PTL, energy conversion efficiency is taken into account to derive total electricity needed for hydrogen production.
Fischer Tropsch is modelled with 73% efficiency and alkaline electrolyzer with 70% efficiency in 2024.

Utility costs (gas and electricity): are based on fixed per-ton usage rates and official market prices per MMBtu (gas) and MWh (electricity) for every market, and every year. These are impactful for PTL but have a small impact on HEFA due to feedstock intensity.

OPEX:
OPEX is fixed as a percentage of CAPEX, empirically derived, and different for every market to reflect labor costs and maintenance costs.

Transport Costs:
This includes the cost to transport feedstock, as well as the cost to transport the finished product, estimated per ton of SAF for every market, empirically based.

CAPEX Amortization via Capital Recovery Factor (CRF):

The CRF was measured as $\frac{r(1+r)^n}{(1+r)^n-1}$ with r the WACC and n the plant lifetime. Total CAPEX is based on empirical data derived from research papers and Department of Energy data as referred to in the model.

$$\frac{(CAPEX * CRF) - Depreciation\ Tax\ Shield}{Annual\ Output}$$

Then, CAPEX per ton of SAF is calculated as:

APPENDIX III: Modeling of levelized production cost of low-carbon fuel (3/3)

We also adjust for tax shields on depreciation and model WACC based on the capital structure (debt/equity split) which differ per country based on empirical data, the risk free rate (10Y swap), credit spread (adjusted with empirical data and decreasing with technology acceptance, and cost of equity defined the required IRR which is also tailored per country based on risk appetite of local equity investors.

Levelized Cost of Production:
Includes the cost per ton of SAF after necessary adjustments for feedstock, hydrogen, utilities, OPEX, CAPEX, and transport.
A minimum offtake price is calculated based on LCoP. We then derive revenue per year of the project, get EBITDA, and EBIT.
The model is dynamic, tied to SAF yield and feedstock efficiency. It is realistic, historically anchored, and based on real prices for feedstock, and utility.

Jet A prices per year are used for comparison over time.

Each input was tailored

APPENDIX IV: Open source attribution

This research utilizes the Natural Language Toolkit (NLTK) version 3.8+ (Bird et al., 2009) under the Apache License 2.0. For sentiment analysis, we employed VADER (Valence Aware Dictionary and sEntiment Reasoner) (Hutto & Gilbert, 2014), which was originally developed under the MIT License, though accessed here through NLTK's implementation.

Additional libraries used include striprtf, pandas, and matplotlib, each with their respective open source licenses.

All license terms have been complied with, and limitations of these tools were addressed through calibration with manually labeled data and expert human review.

Citations:

Bird, S., Klein, E., & Loper, E. (2009). Natural Language Processing with Python. O'Reilly Media.

Hutto, C.J., & Gilbert, E.E. (2014). VADER: A Parsimonious Rule-based Model for Sentiment Analysis of Social Media Text. Eighth International Conference on Weblogs and Social Media (ICWSM-14). Ann Arbor, MI.

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Thank you!