Public perceptions of hydrogen risks, costs and benefits: Insights from a multigroup analysis

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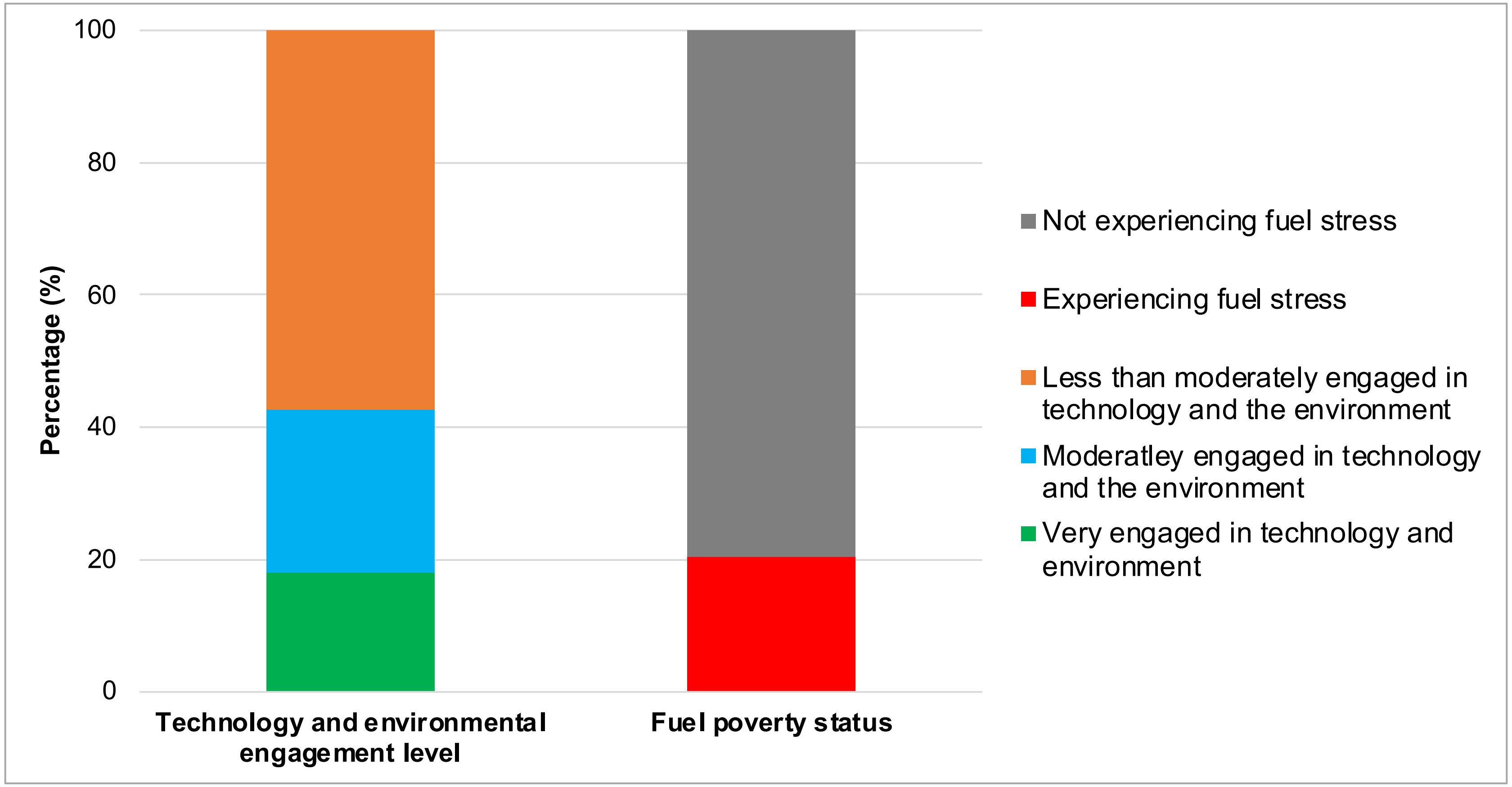
Presentation agenda and research materials

- Focus on domestic hydrogen acceptance (‘***hydrogen homes***’) – UK context
- Research design for online survey
- Conceptual framework
- Survey results (descriptives)
- Modelling results (incl. ***Importance-performance map analysis***).
- Multigroup analysis of safety perceptions
- Qualitative results on safety perceptions
- Safety benefits vs safety risks
- Consumer perspectives towards domestic hydrogen (‘***H2 acceptance matrix***’)
- Concluding remarks

Multigroup research design to explore consumer heterogeneity



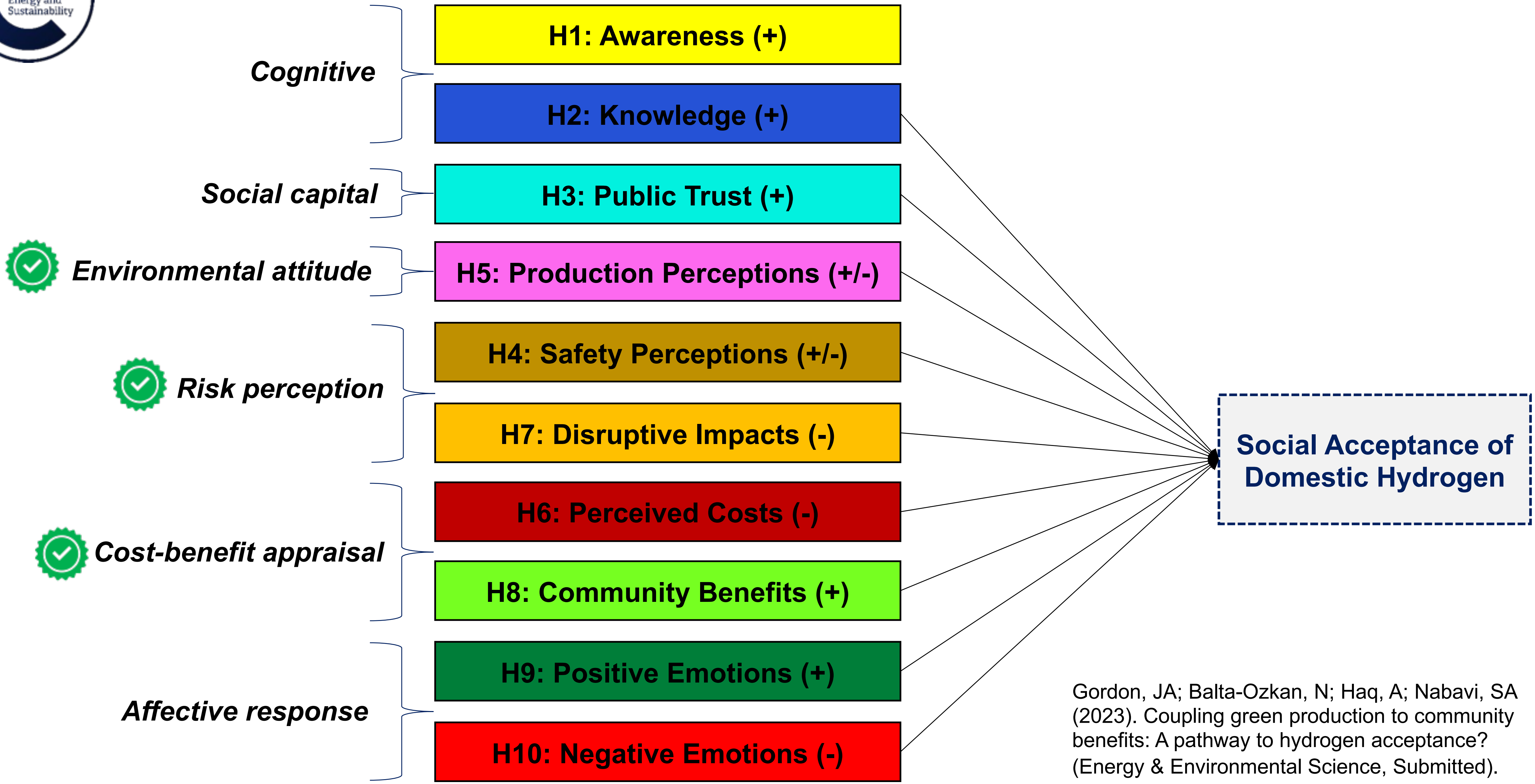
See slide 22 for a further breakdown!

Consumer sub-group	Sample size (%)
MEG: Moderately Engaged in technology and the environment	458 (24.8)
VEG: Very Engaged in technology and the environment	331 (17.9)
FSG: Fuel stressed (and less than moderately engaged in the environment)	379 (20.5)
BLG: Baseline Group (none of the above)	677 (36.7)

Data collection period: Oct–Dec 2022

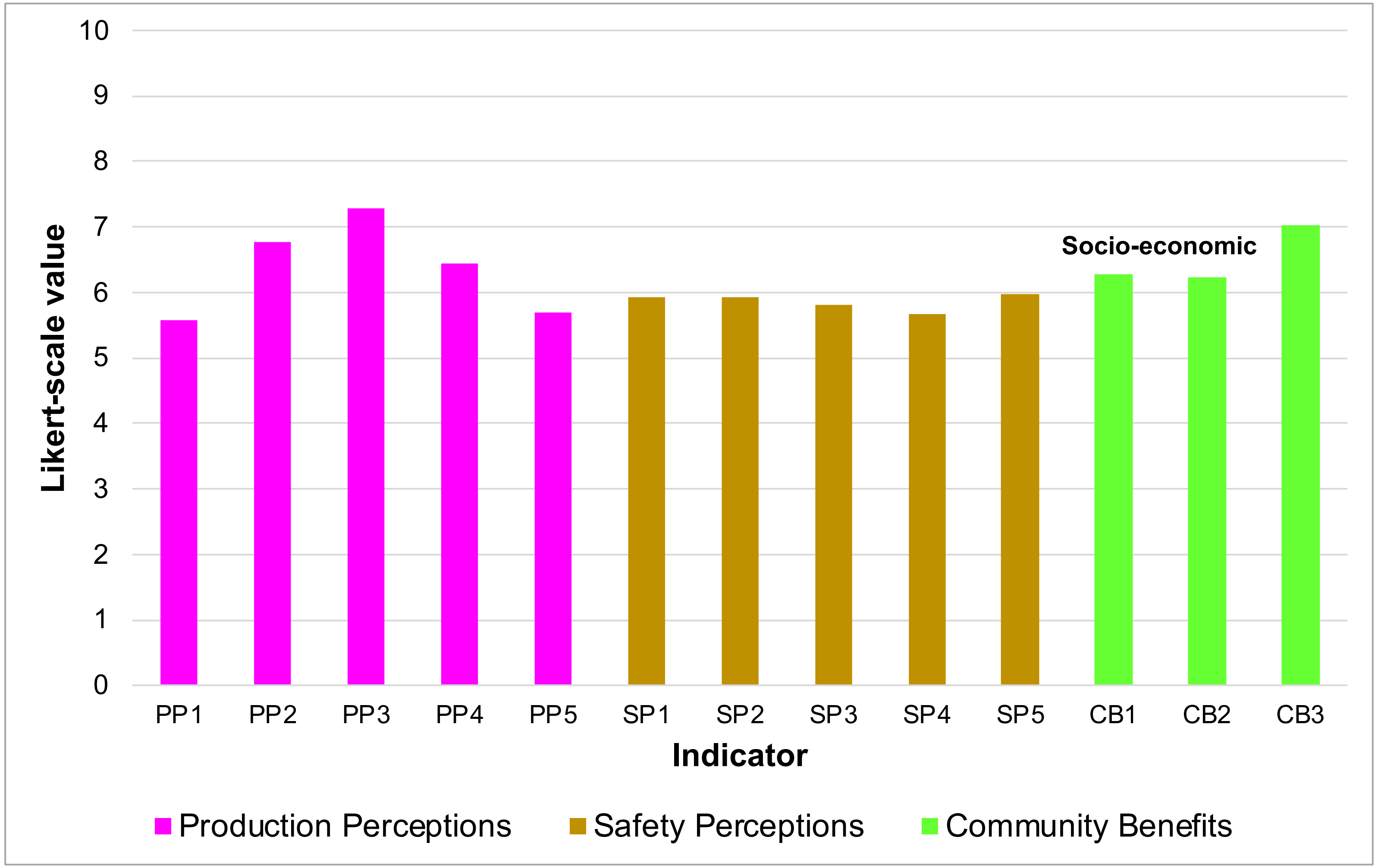
Total sample = 1845 (Qualtrics survey)

Domestic Hydrogen Acceptance Model (DHAM): Constructs and dimensions



Gordon, JA; Balta-Ozkan, N; Haq, A; Nabavi, SA (2023). Coupling green production to community benefits: A pathway to hydrogen acceptance? (Energy & Environmental Science, Submitted).

Survey results on safety, production and community benefits

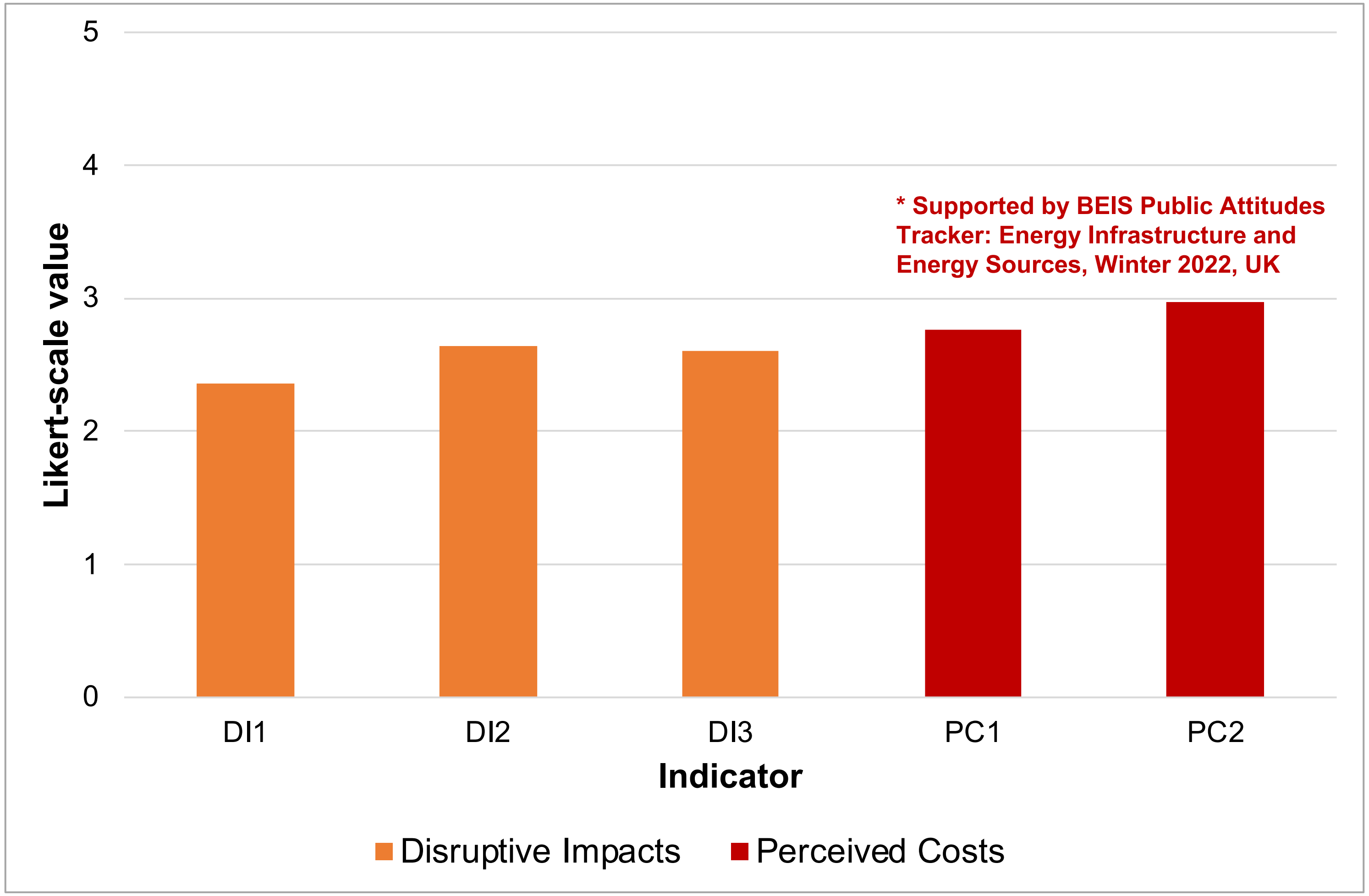


PP1 = Blue H2 short-term
PP2 = Blue H2 long-term (2030+)
PP3 = Green H2 short-term
PP4 = Green H2 long-term (2030+)
PP5 = 'Twin-track' approach

SP1 = H2 boilers
SP2 = HS hobs
SP3 = H2 pipelines
SP4 = H2 underground storage
SP5 = H2 safety level (production, storage, transportation and domestic use) ***compared to natural gas***

CB1 = Economic benefits (e.g. job opportunities and income security)
CB2 = Social benefits (e.g. reduced levels of fuel poverty and improved health)
CB3 = Environmental benefits (e.g. lower carbon emissions and better air quality)

Survey results on perceived ('soft') risks and perceived costs



DI1 = Inconvenience at street-level (noise, traffic etc.)

DI2 = Temporary disconnection from gas grid (i.e. for up to 3 days during summer)

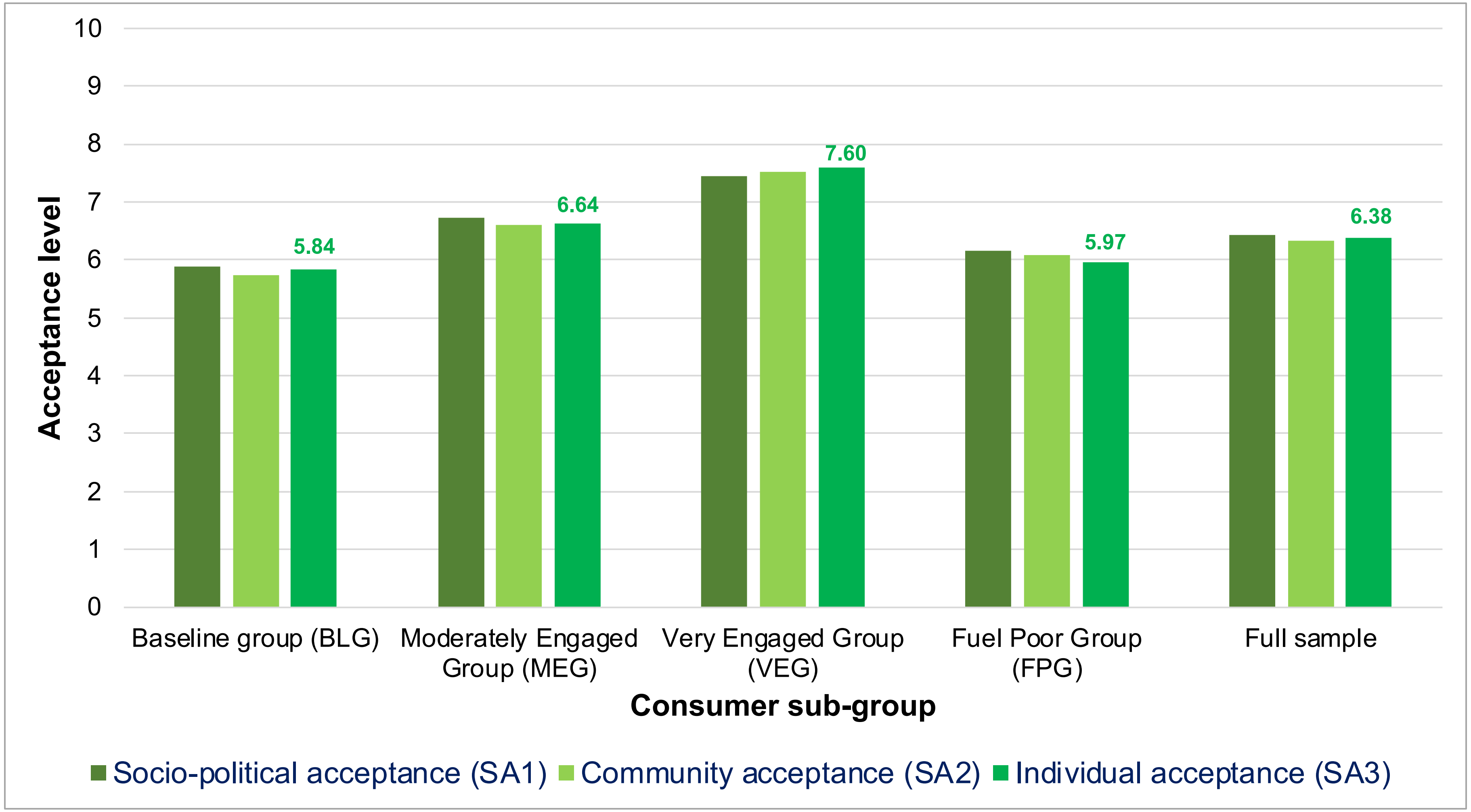
DI3: Visits from engineers and technicians during switchover period

PC1 = Negative impact on UK energy security (i.e. reliability of energy supply)

PC2: Negative impact on fuel poverty (UK wide)

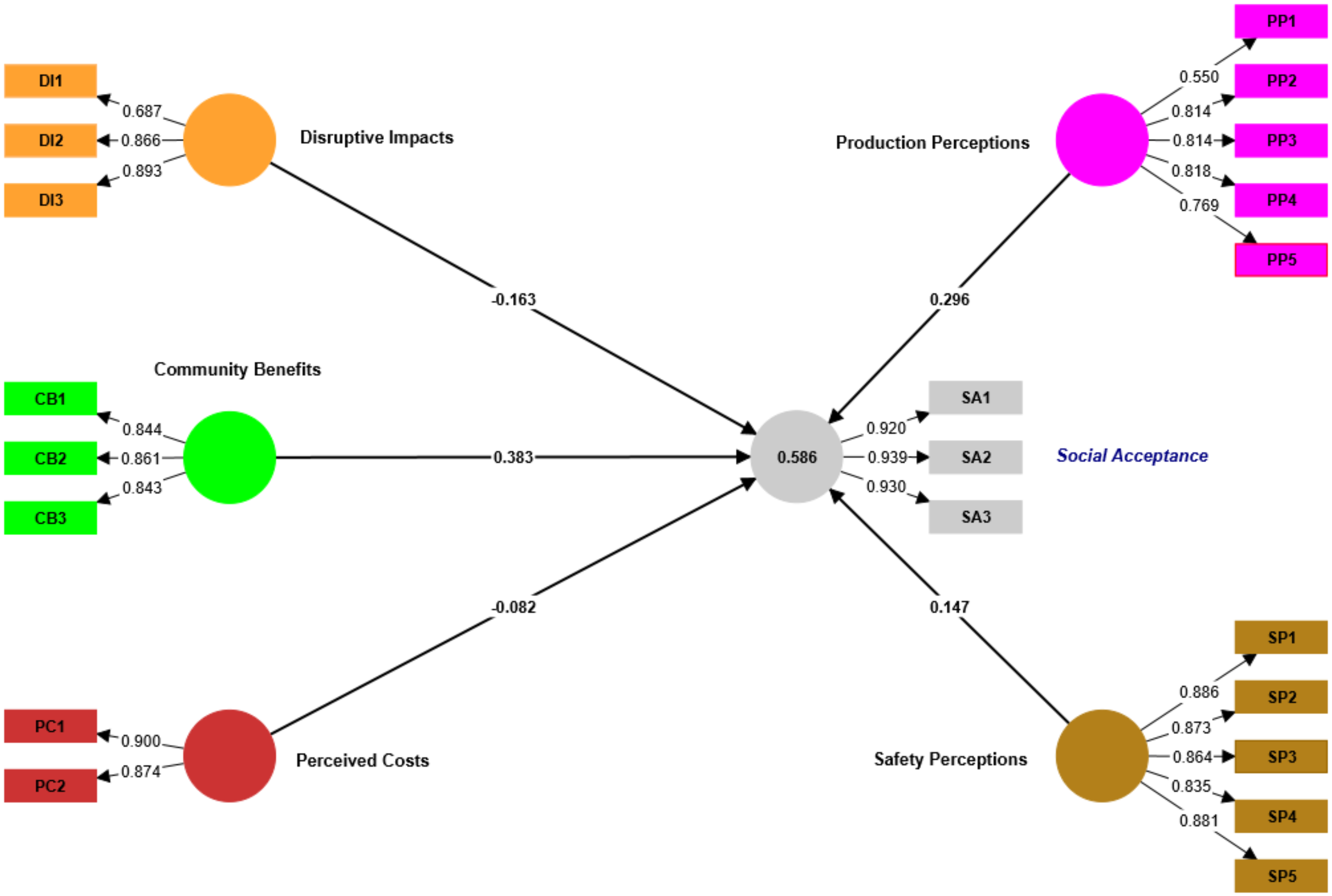
*PC3 = Negative environmental impacts (not validated for modelling purposes)

Domestic hydrogen acceptance across sub-groups and sample



SA1: Domestic H2 becoming a critical part of the UK's energy future
SA2: Hydrogen replacing natural gas in your local area before 20230
SA3: Switching your home to both H2 heating and H2 cooking before 2030

(1) Results from structural equation modelling (PLS-SEM)

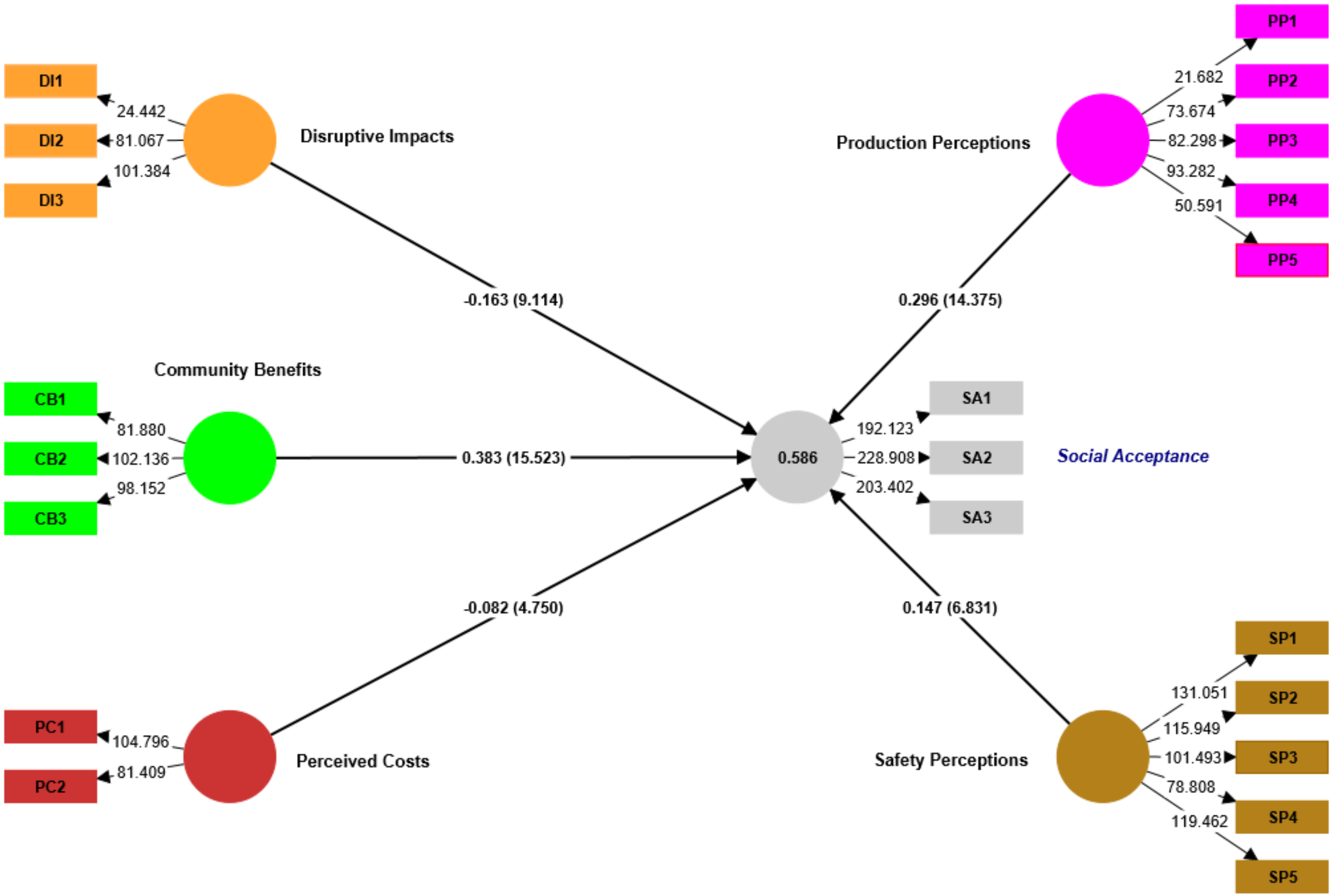


Reflective measurement model

Our measurement model was validated in four stages:

- ***Indicator reliability:*** Indicator loadings (bivariate correlation) should be >0.70, ideally. And >0.5 for exploratory research.
- ***Internal consistency reliability:*** the indicators are correlated with one another sufficiently
- ***Convergent validity:*** average variance extracted > 0.5
- ***Discriminant validity:*** the constructs are empirically distinct from one another

(2) Results from PLS-SEM with t-values included



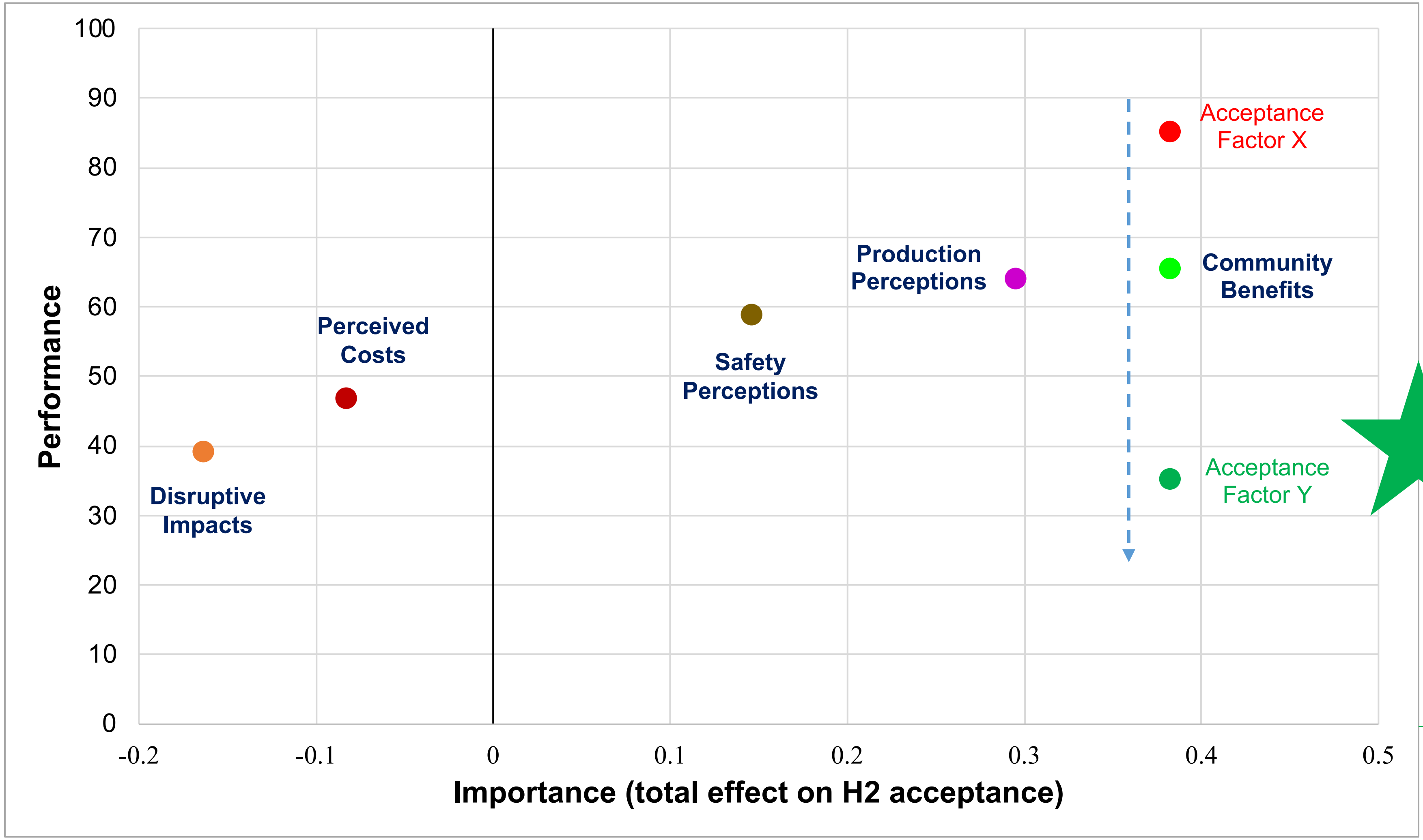
The model – composed of five endogenous (independent) constructs – explains close to **60%** of the exogenous construct, ***social acceptance of domestic*** hydrogen

- Moderate to high in-sample predictive capacity for an exploratory model
- We also achieve high out-of-sample predictive power (outperforming benchmark models – 'CVPAT' test)*

	P-value	t-value	Path coefficient
Community Benefits	0.000	15.523	0.383
Disruptive Impacts	0.000	9.114	-0.163
Perceived Costs	0.000	4.750	-0.082
Production Perceptions	0.000	14.375	0.296
Safety Perceptions	0.000	6.831	0.147

*Cross-validated predictive ability test

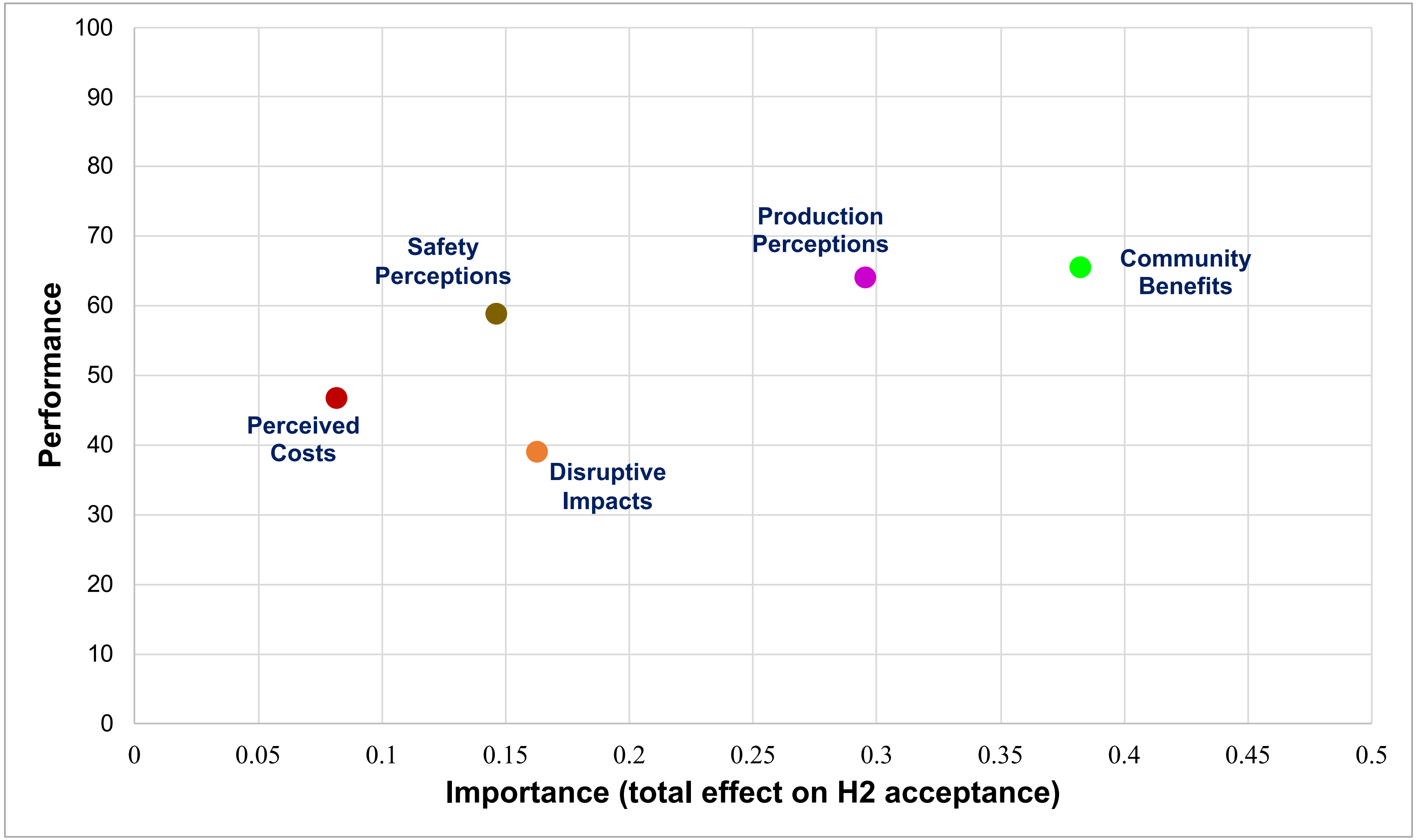
Importance-performance map analysis (Construct level)



Less scope for improving performance in Factor X compared to Factor Y

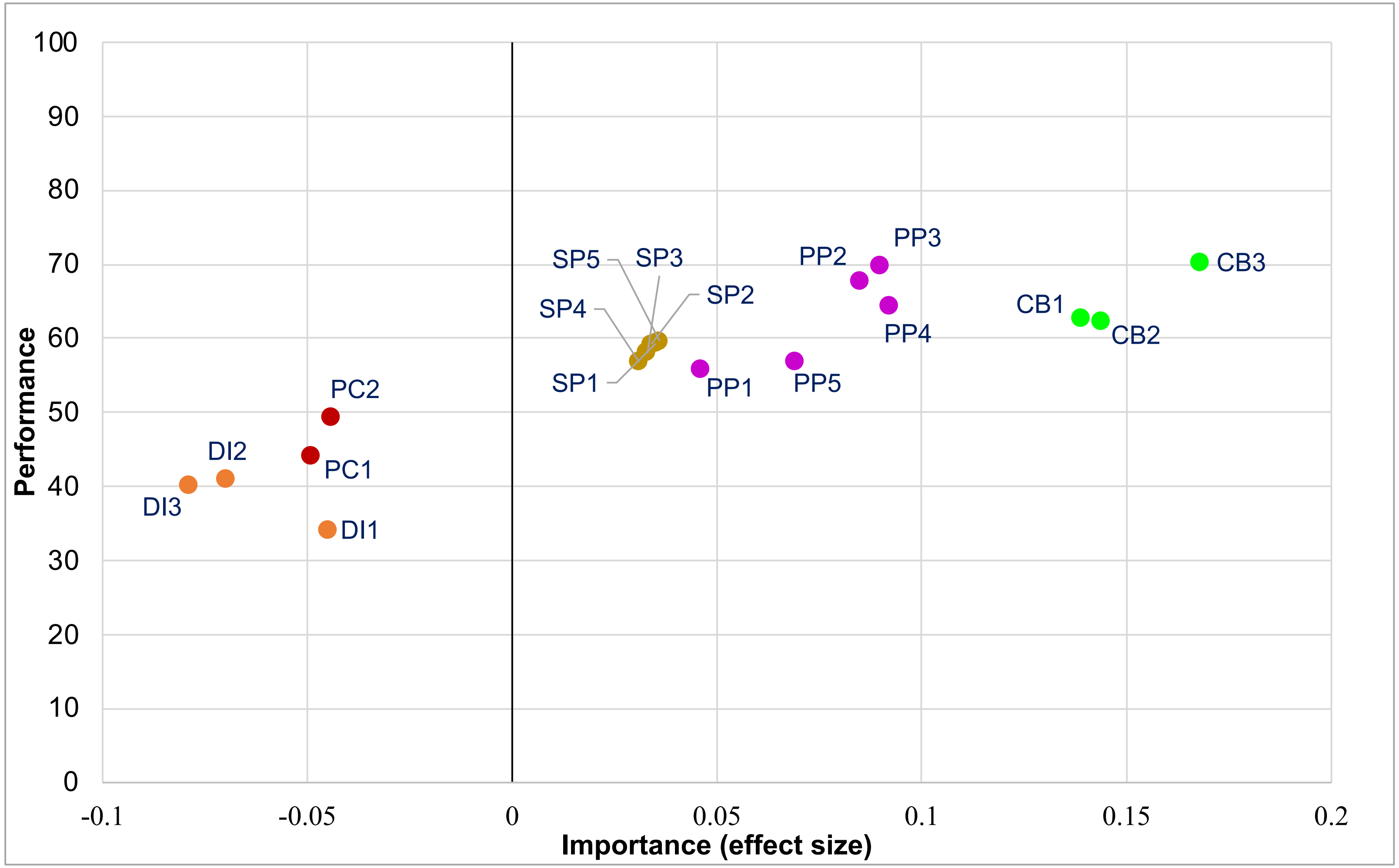
Priority zone ('quadrant') of strategic importance for supporting social acceptance

Coupling green production to community benefits: a pathway to social acceptance?



*Negative scale/axis removed to enhance readability

Extending the IMPA to the indicator level – environmental benefits (CB3) links to social acceptance



- Environmental benefits is the most impactful indicator (**CB3**)
- Economic and social benefits (**CB1** & **CB2**) are next priority
- Blue H_2 production in the short-term (**PP1**) is the least impactful among Production indicators, underlining the preference for green H_2 (**PP3** and **PP4**), although blue H_2 in the long-term (PP2) is relevant
- Safety perceptions (**SP1–SP5**) are clustered together
- Temporary disconnection from the gas grid (**DI2**) and disruption caused by engineers/technicians (**DI3**) appear more relevant than other negative factors (DI1, PC1&2)

Path coefficients for each exogenous construct (predictor)

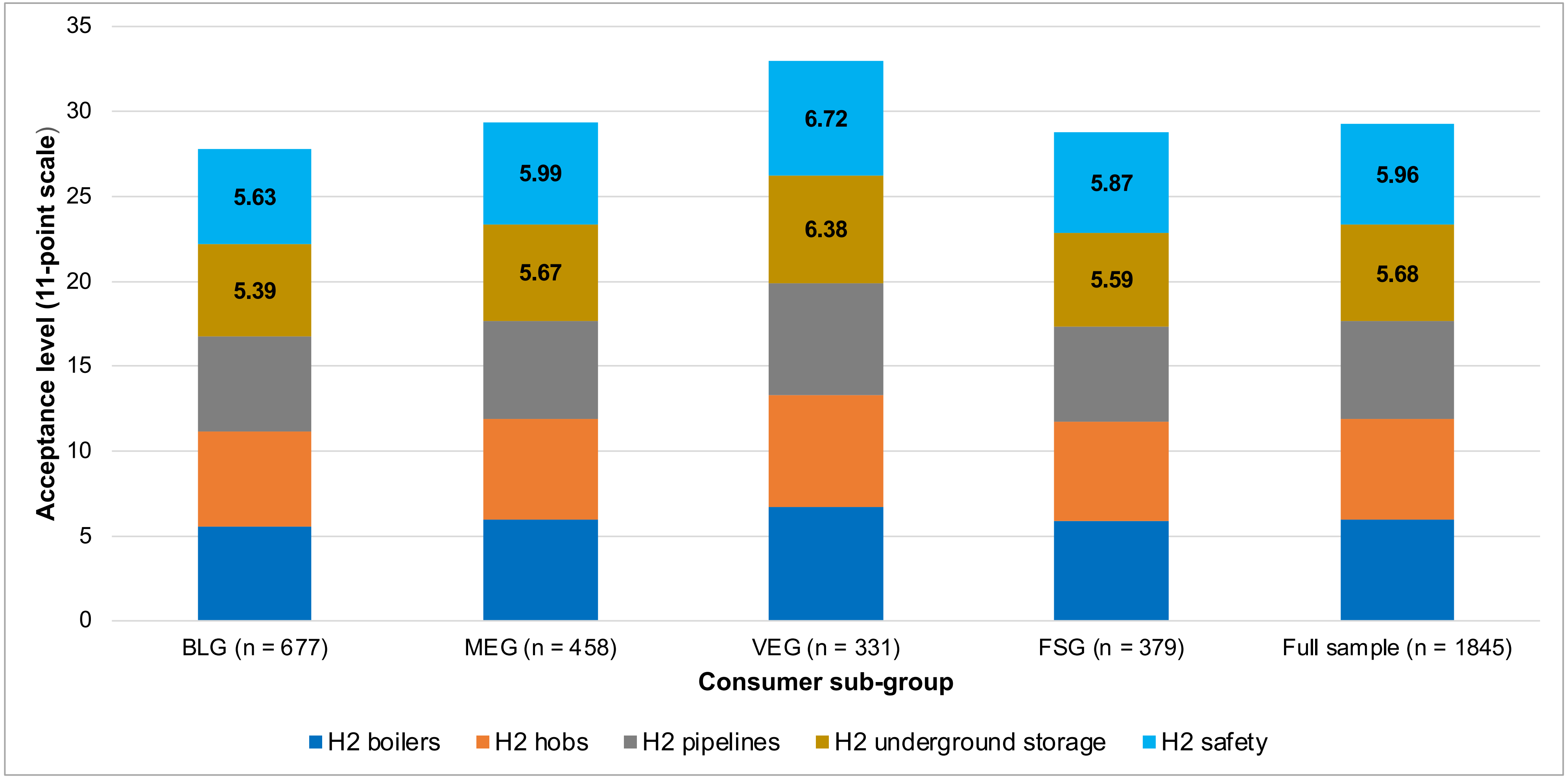
	Baseline Group (BLG)	Moderately Engaged Group (MEG)	Very Engaged Group (VEG)	Fuel Stressed Group (FSG)
Community Benefits	0.385	0.351	0.404	0.364
Disruptive Impacts	-0.169	-0.195	-0.129	-0.183
Perceived Costs	-0.077	-0.125	-0.068	-0.099
Production perceptions	0.249	0.256	0.330	0.301
Safety Perceptions	0.181	0.124	0.076	0.164
R-squared	0.538	0.562	0.537	0.596

The acceptance constructs in the model are highly consistent across consumer sub-groups (no statistically significant differences)

*H2 acceptance levels **do** vary across some sub-groups, but the relationships are relatively homogenous…*

See slides 23-26 for visual outputs

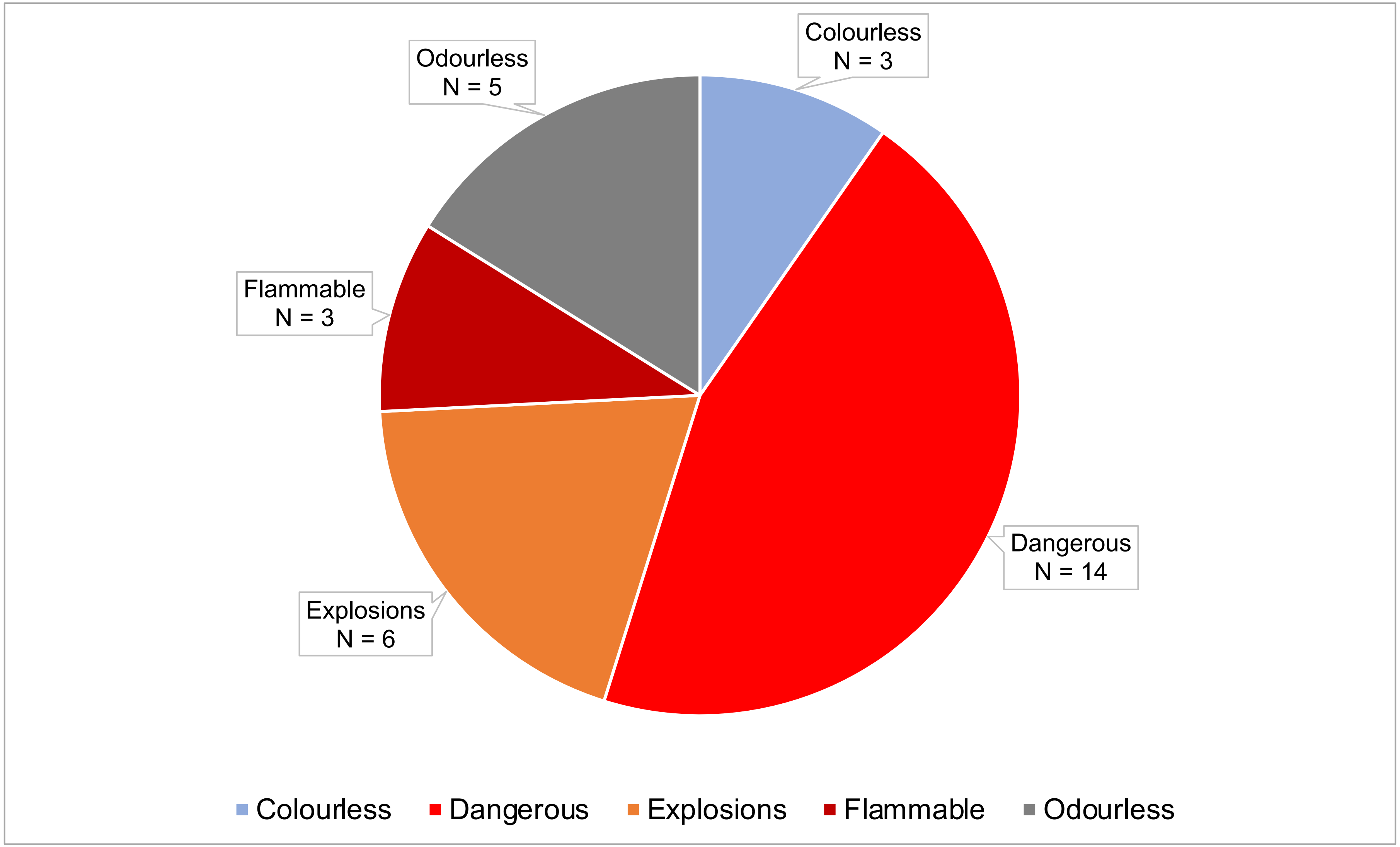
Multigroup analysis of safety perceptions



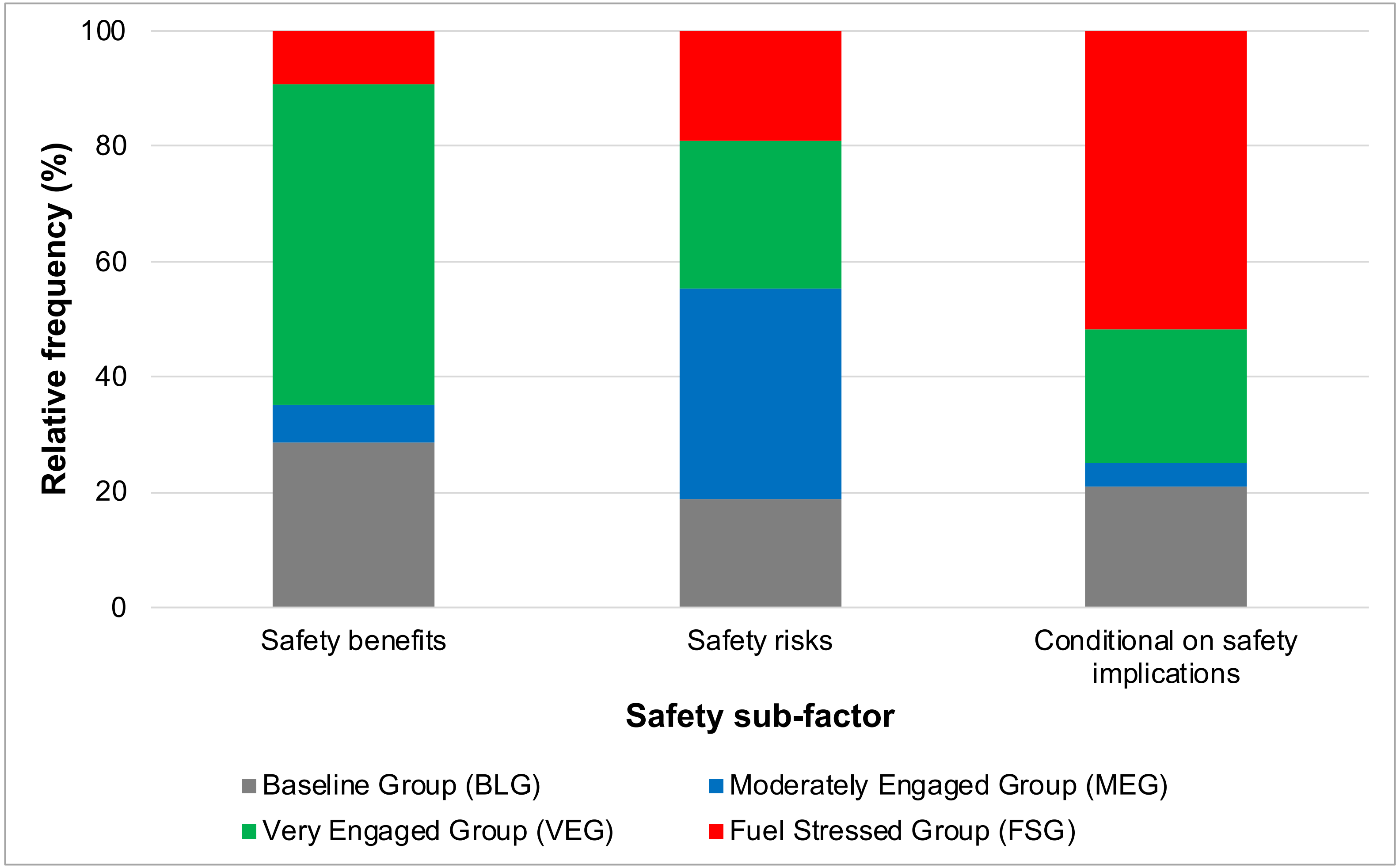
Snapshot of negative safety perceptions and social representations

*From what I understand, hydrogen is **very** dangerous, and it wouldn't be advisable for use in the general public* (MEG 24)	*The only slight concern I have is the fact it is odourless, so I am unsure if people would be able to detect gas leaks through smell* (VEG 208).
I always associate hydrogen with nuclear, probably why I am not overly enthusiastic (MEG 46)	*Scared as no controls appear to be in place for safety issues* (BLG 336)
Safety wise, I would be reluctant to use this…the images of the hydrogen balloons igniting come to mind (MEG 268)	*Concerned about safety and the problems of brittleness when components are exposed to hydrogen over an extended period* (VEG 17)
Fearful about explosiveness (VEG 27)	*Not very comfortable with something so flammable* (MEG 161)

Breakdown of negative safety perceptions (N = 42)



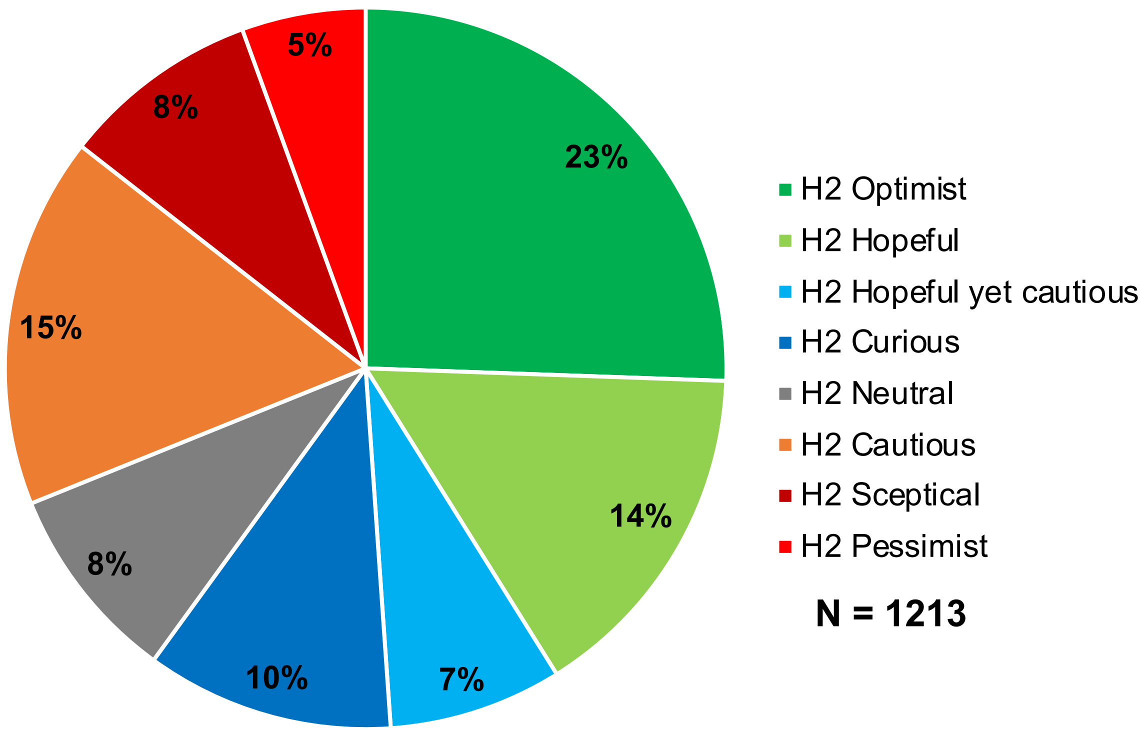
Breakdown of consumer responses on safety: N = 104 (4.8%)



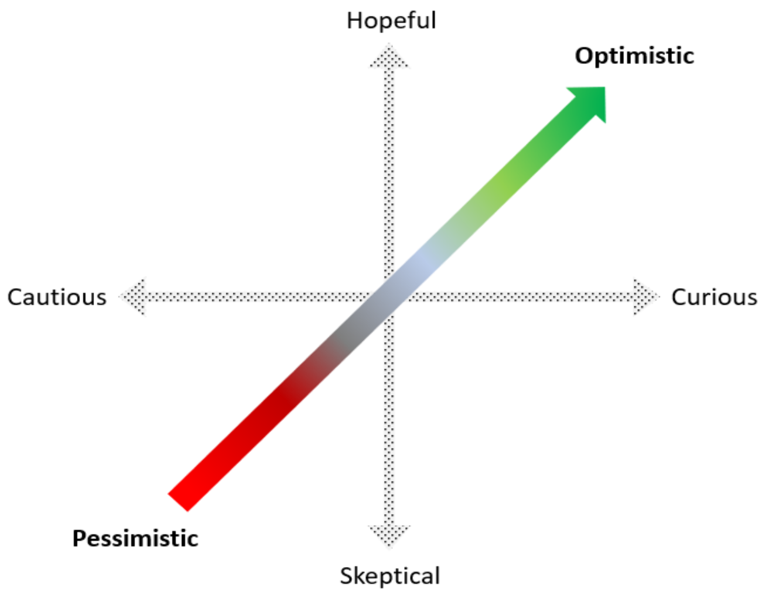
Absolute frequency shown on Slide 27

- The ***Safety benefits sub-factor*** is statistically different across groups (p = 0.06) due to the VEG being more positive/aware
- However, the null hypothesis is retained for ***safety risks*** (p = 0.137) and for ***conditional on safety implications*** (p = 0.245)

(Re-)conceptualising domestic hydrogen acceptance



Domestic hydrogen acceptance matrix



Gordon, JA; Balta-Ozkan, N, Nabavi, SA (2023). Hopes and fears for a sustainable energy future: Enter the hydrogen acceptance matrix (Energy Policy, Submitted).

Concluding remarks (1)

- Unpacking hydrogen acceptance requires a highly multi-dimensional approach to account for a wide range of attitudes **(which can be conflicting!)**
- Environmental attitudes, risk perceptions and cost-benefit appraisal are among some of the key dimensions
- **Green H2 production** is preferred over blue H2, *although temporal dynamics as perceived by consumers may not align with the 'twin-track' approach*)
- Safety perceptions are highly consistent across different metrics (storage, transport etc.)
- Environmental benefits may prove the prime acceptance factor, but must be accompanied by socio-economic benefits
- The disruptive impacts of the transition may prove relatively tolerable, *although temporary disconnection from the gas grid must be that (temporary!) and energy vulnerabilities should be accounted for*
- Hydrogen homes should not exacerbate fuel poverty pressures – **if a socially acceptable transition is to be secured!**

Concluding remarks and emerging analyses

- **Technology and environmental engagement** are drivers of domestic hydrogen acceptance
- **Fuel stress** may encourage support for something better (cheaper, cleaner, safer!)
- Technology and environmental engagement raises awareness over the potential safety benefits of H2
- Our survey results point towards some degree of optimism and hope for a domestic hydrogen future, but significant work is needed to convert neutral attitudes into positive ones, while negative perspectives need to be better understood and responded to…
- Overall, coupling **green H2 production** to **community benefits** may be the strongest pathway to securing social acceptance for hydrogen homes
- Forthcoming research outputs engage with *fuel poverty perspectives*, *the trust dynamics of the transition*, and *socio-demographic factors* to help better unpack the **emerging contours of domestic hydrogen acceptance**

Publications and link to materials

- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Coupling green production to community benefits: A pathway to domestic hydrogen acceptance? Energy & Environmental Science (***submitted***)
- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Hopes and fears for a sustainable energy future: Enter the hydrogen acceptance matrix. Energy Policy (***submitted***)
- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Towards a unified theory of domestic hydrogen acceptance: A call for theoretical rigour in energy acceptance studies (***submitted***)
- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Divergent consumer preferences and visions for cooking and heating technologies in the United Kingdom: Make our homes clean, safe, warm and smart! Energy Research & Social Science
- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Gauging public perceptions of blue and green hydrogen futures: Is the twin-track approach compatible with hydrogen acceptance? International Journal of Hydrogen Energy.
- Gordon JA, Balta-Ozkan N & Nabavi SA (2023) Socio-technical barriers to domestic hydrogen futures: repurposing pipelines, policies, and public perceptions, Applied Energy, 336 (April) Article No. 120850.
- Gordon JA, Balta-Ozkan N & Nabavi SA (2022) Beyond the triangle of renewable energy acceptance: the five dimensions of domestic hydrogen acceptance, Applied Energy, 324 (October) Article No. 119715.
- Gordon JA, Balta-Ozkan N & Nabavi SA (2022) Homes of the future: unpacking public perceptions to power the domestic hydrogen transition, Renewable and Sustainable Energy Reviews, 164 (August) Article No. 112481.

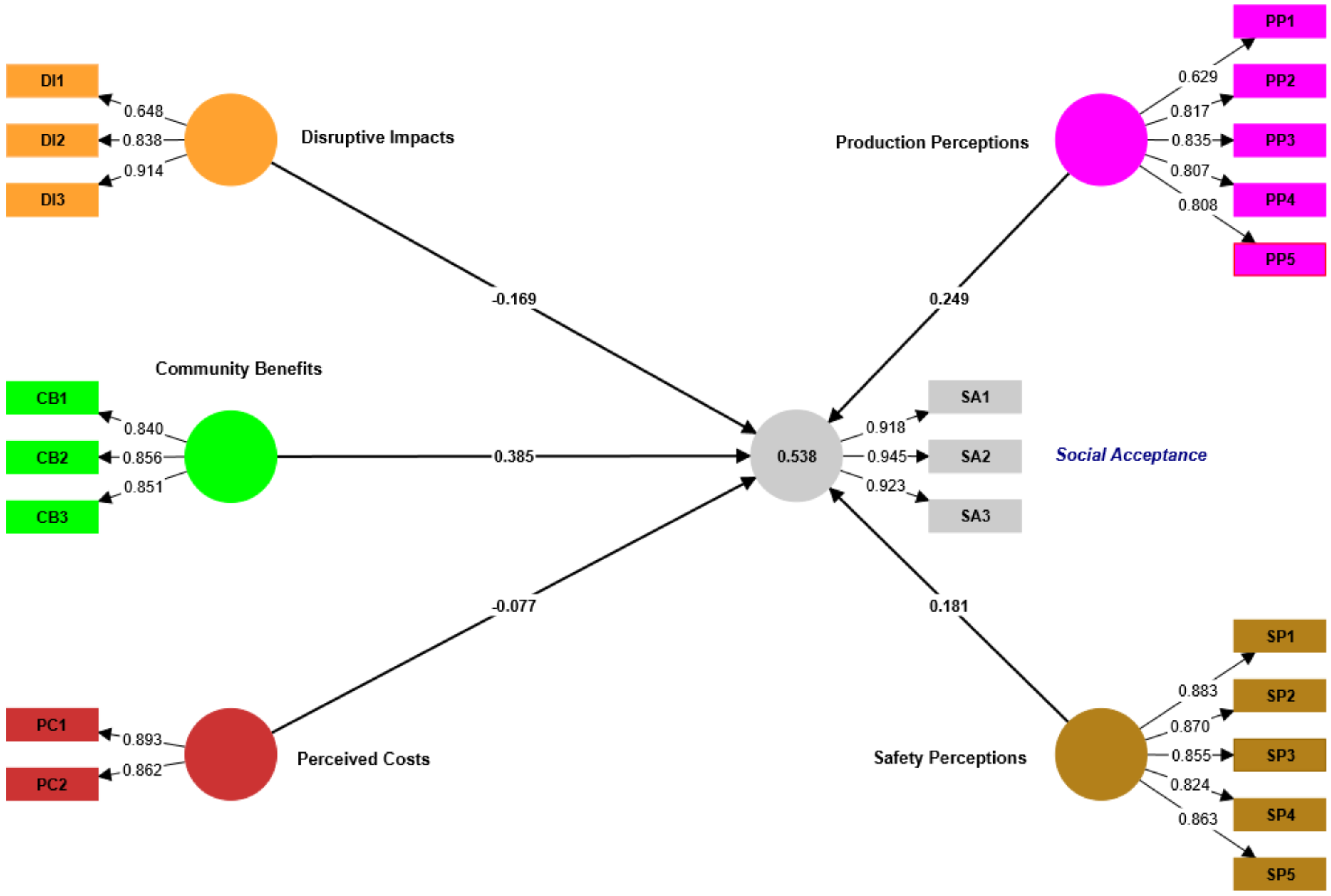
https://www.cranfield.ac.uk/people/joel-gordon-28447781

https://cord.cranfield.ac.uk/articles/online_resource/Qualitative_responses_to_Hydrogen_Homes_H2H_Online_Survey_2022_docx/23585166

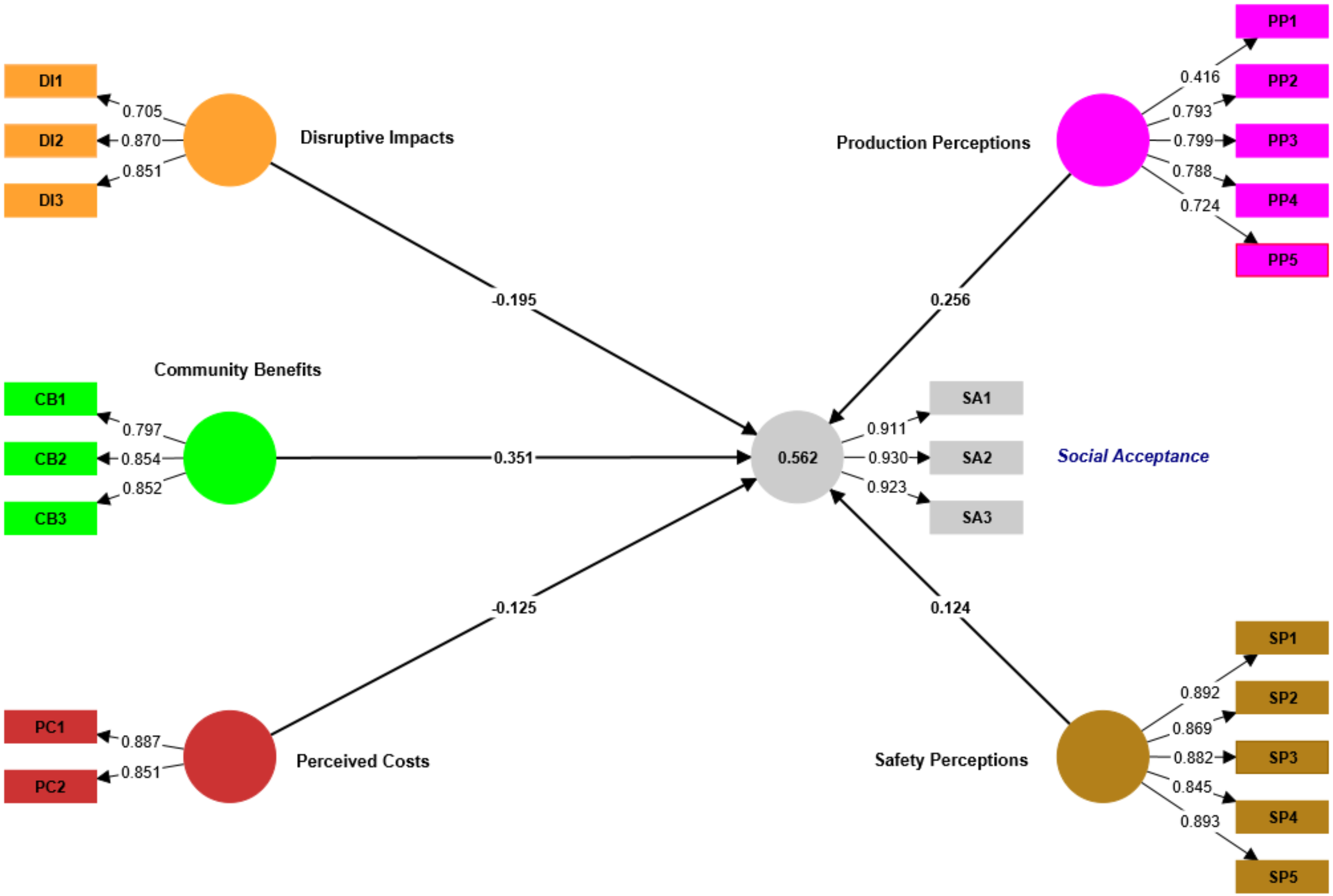
Bonus materials: Composition of consumer sub-groups by filters

Sub-group	Total sub-sample size (%)	Consumer specifications
Moderately Engaged Group (MEG)	N = 458 (24.8)	• Moderate level of knowledge and awareness of renewable energy technologies • At least moderate level of interest in adopting new energy technologies • Moderate interest and engagement in environmental issues • Not experiencing fuel stress
Very Engaged Group (VEG)	N = 331 (17.9)	• High level of knowledge and awareness of renewable energy technologies • At least moderate level of interest in adopting new energy technologies • Strong interest and engagement in environmental issues • Not experiencing fuel stress
Fuel Stressed Group (FSG)	N = 379 (20.5)	• Less than moderate level of knowledge and awareness of renewable energy technologies • Less than moderate level of interest in adopting new energy technologies • Less than moderate level of interest and engagement in environmental issues • **Living in fuel poverty or experiencing high levels of fuel stress**
Baseline Group (BLG)	N = 677 (36.7)	• Less than moderate level of knowledge and awareness of renewable energy technologies • Less than moderate level of interest in adopting new energy technologies • Less than moderate level of interest and engagement in environmental issues • Not experiencing fuel stress
Total	1845	

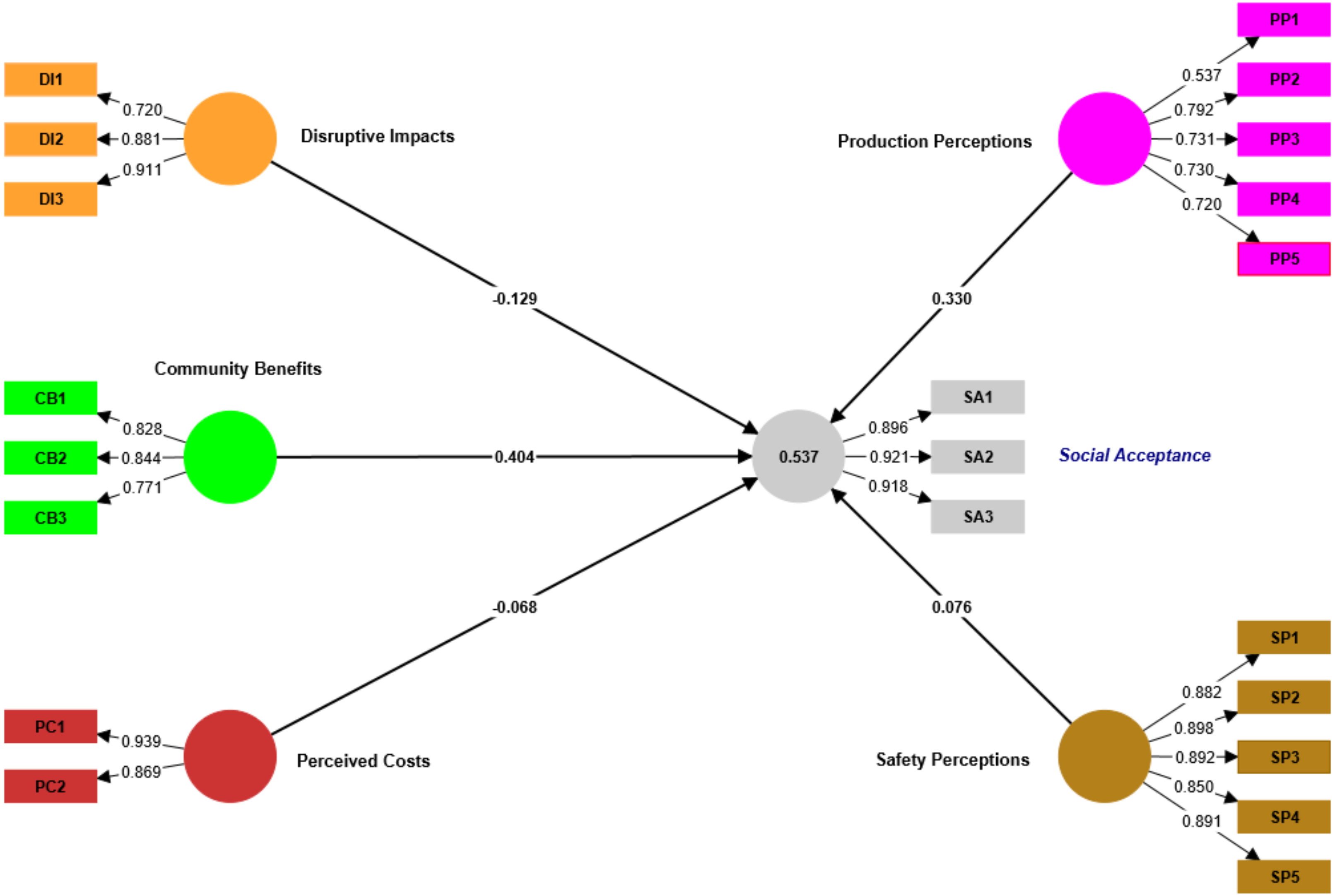
Modelling results for the Baseline Group (BLG)



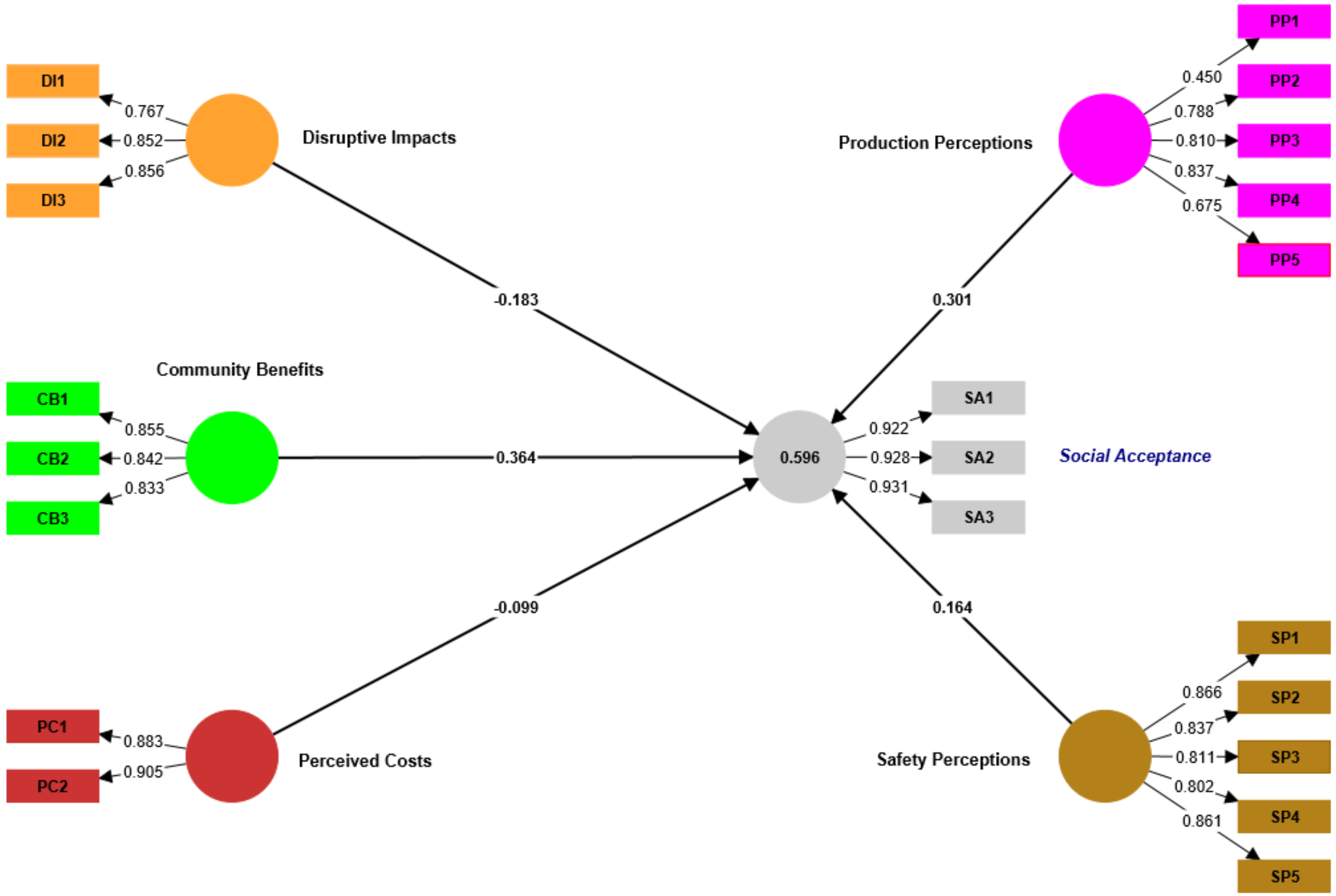
Modelling results for the Moderately Engaged Group



Modelling results for the Very Engaged Group (VEG)



Modelling results for the Fuel Stressed Group (FSG)



Comparison of safety acceptance sub-factors across groups