GRETA
GREEN
ENERGY
TRANSITION
ACTIONS

D3.6
Case study 6 report: Electric autonomous and connected mobility network

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Deliverable nature	Report
Dissemination level (Confidentiality)	Public (PU)
Delivery date	2022-12-31
Version	v.1
Total number of pages	67
Keywords	CCAM, autonomous driving, self-diving cars, energy citizenship, energy transition, mobility policy, energy policy, innovation and behaviour, sustainable behaviour, behavioural insights
Cite as	Montalvo, C. and S. Jansen (2023). Case study 6 report: Electric autonomous and connected mobility network. D3.6 of the Horizon 2020 project GRETA, EC grant agreement no 101022317, The Hague, The Netherlands
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022317.

Disclaimer and acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022317.

Executive summary

Connected and cooperative automated mobility (CCAM) refers to an infrastructure of transport whose individual vehicles or platooning vehicle units perform an autonomous "self-driving" without human intervention. **CCAM is a new concept of mobility that promises to bring redical increases in road safety and efficiency of the road transport system.** The policy aim is to increase the overal efficienty of the mobility system. All inefficiencies and traffic accidents have a direct impact on the energy efficiency of the transport and mobility system. These being caused by destruction of mobility assets (destruciton of vehicles that must be replaced), damages in roads and congestion. All these undersired ineficiencies are to be ammeliorated by the advent of CCAM in conjunctions with the deployment of electrification of the vehicle park.

This deliverable is part of WP3 and based on D1.1 and D1.3 of WP1. The aim of WP3 is to summarize and evaluate the GRETA case studies to understand the structural factors that affect the emergence and development of energy citizenship. The report offers an overview of the policy landscape as well as it defines the behaviours that citizens, policymakers and business would display in relation to the development and deployment of CCAM to support the clean energy transition. It identifies the potential drivers and barriers for engagement in CCAM in the three actors mentioned. In addition, it measures and identify the key drivers and barriers in citizens to engage in CCAM. While doing so it validates the theoretical framework guiding the enquire testing a number of hypotheses that in general are confirmed by the analyses.

There are rich insights in qualitative and quantitative data but three key conclusions that merit mention:

- **The framework:** The framework proposed to enquire about the emergence of energy citizenship lead us to select specific cases that would demonstrate beyond a sociological and policy concept. This is, what means in practice for citizens to engage in energy citizenship, and what would motivate such engagement. The theoretical framework lead us to the selection of a number of cases that would demonstrate in practice, what citizens could do to contribute to the energy transitions.
- **The trends identified in CCAM engagement and drivers:** The descriptive analysis of the trends in engagement and drivers show that currently there is little engagement in CCAM, this reflects the level of development and deployment of the Level 3 of automation. It cannot be otherwise that the data reflects that. It worth to highlight that the level of knowledge about the CCAM transition and capacity to engage is lacking in the citizenry, engagement must be promoted by business and government. Similarly
- **The validity of the framework:** The tests conducted in the hypothesis posed at the outset of this enquire produced confirmatory results. The reliability of the scales was found not only satisfactory but high, validating the reliability of

measurements of the constructs of interest for all scales used. The structure of the model was confirmed by a multidimensional scale analysis, testing the validity of the six constructs that integrate the framework. The analysis indicated that up to 63% of the variance was explained by the six components. This also indicated a clear cut of six dimensions in the empirical data, indicating a correspondence between the theoretical framework and empirical structure of the survey data. The analytical framework enabled the reduction and efficient analysis of a large array of data that uncover hidden patterns that drive engagement in energy citizenship. Such hidden patterns are not recognizable in the descriptive statistics nor in the qualitative stage of the enquire.

- **General overview of policy and engagement of citizens:**
  The energy transition and climate resilience and the transition to autonomous mobility are two trends that will influence each other in the long run. The mutual influence of different drivers creates positive synergies. Saying this, the regulatory framework for the development and deployment of the most advanced levels of automation is extensive and complex. The advent of this relatively new regulatory framework will take time to be implemented across member states. It will require an effort not only of national authorities but also business to adapt and operate in this new regulatory framework. Business and national authorities are still at the early dawn of awareness of the implications of the advent of the digital mobility and its regulatory system. At the side of the end user of these technologies many of these regulations are not visible as they are embedded in the systems that provide the service of mobility, that is the vehicle and the enabling infrastructure. Most citizens operate their vehicles not being aware of the regulatory system supporting the operation of the vehicle park beyond aspects and issues related to private insurance, road rules and licencing. The advent of new vehicles with CCAM capabilities might require more awareness of such regulatory matters in other to better adopt and use these new systems.
- **Key message to policymakers and business:** The engagement in CCAM will be strongly moderated by age, education and income levels. Second factor concerns the enablers of engagement in the following order: like knowledge (technology, benefits and cost, new rules and regulations) and the regulatory framework. Barring the above, the cooperative and digital nature of the new technology seem to demand also a shift towards a culture and social contract based in values of “community sharing and equality matching” in contrast with the current “market pricing and authority ranking”. This calls for a more decisive engagement of citizens in the development and deployment of CCAM. Taking behavioural drivers into consideration into the design of policies promoting change, promoting the energy transitions is relatively new. This brings a challenge not only of designing the appropriate format of a new social contract. Also it brings the challenge of delivering a policy mix that tackles information provision, enabling power to engage and shaping the modality of interaction between actors. If we believe the empirical evidence provided in this case study, this is a new territory that must be explored and developed in order to support the energy transition.

The report is structured around five chapters, the introduction sets the rationale of the case study, the policy landscape and the research design. Chapter two presents in a synthetic form (tables) the elicited barriers and drivers that might affect the engagement in CCAM in citizens, government and policymakers. Chapter three presents the empirical findings of the survey and the validation of the framework used to guide the case study and survey. Chapter four discusses the findings and offers major traits that have implications for policy design in the promotion of CCAM amongst citizenry in Europe. The last chapter offers last conclusions and reflection on the research conducted.

Project information

Grant agreement No.	101022317
Acronym	GRETA
Full title	GReen Energy Transition Actions
H2020 Topic	H2020-LC-SC3-2020-NZE-RES-CC
Project URL	www.projectgreta.eu

Document information

	Number	Title
Deliverable	D3.6	Case study 6 report: Electric autonomous and connected mobility network
Work package	WP3	Data gathering from case studies and multinational citizen consultation
Task	T3.4	Task 3.4 Synthesis and validation of case study results

Delivery date	Contractual: M20, Actual: M20
Nature	☒Report ☐Other ☐ORDP
Dissemination level	☒Public ☐Confidential
Authors (partners)	Carlos Montalvo, Sven Jansen
Reviewers (partners)	Izaskun Jimenez Iturriza (Tecanalia), Hanna Kuittinen (Tecnalia)
Summary (for dissemination)	This report presents the results of a case study analysing connected and cooperative automated mobility
Keywords	CCAM, autonomous mobility, autonomous mobility acceptance, autonomous car acceptance, self-driving car adoption, self-driving car diffusion, CCAM acceptance, drivers and barriers to autonomous car,

Version	Date	Description
V.0	2022.12.14	Draft prepared
V.1	2022.12.23	Sent for submission

Table of contents

List of figures

List of tables

Abbreviations and acronyms

CCAM	Connected and cooperative automated mobility
AVs	Automated vehicles
EVs	Electric vehicles
AEVs	Automated electric vehicles
ENG	Engagement level
OUT	Outcomes towards GRETA (this is a **cognitive** construct see p49-50 in D1.1)
SN	Social and personal norm (this is a **normative** construct)
AG	Agency to engage in GRETA (this is an **instrumental** construct)
RM	Relational model mediating interactions (this is a **relational-affective** construct)
EVR	Environmental risk perception (cognitive construct)
ER	Economic risk stemming from GRETA engagement (cognitive construct)
SO	Social outcomes from GRETA (cognitive construct)
CP	Community influence to engage in GRETA (normative construct)
MP	Market influence to engage in GRETA (normative construct)
RP	Regulatory influence to engage in GRETA (normative construct)
TC	Technical knowledge, resources and timing to engage in GRETA (instrumental construct)
OC	Organisational knowledge, resources and timing to engage in GRETA (instrumental construct)
AR	Authority ranking (relational-affective)
CS	Community sharing (relational-affective)
EM	Equality matching (relational-affective)
MP	Market pricing (relational-affective)
RMT	Relational models theory (relational-affective)
SE	Social enterprise
SME	Small-medium enterprises

1 Introduction

1.1 Case study: Connected and cooperative automated mobility

Connected and cooperative automated mobility (CCAM) refers to an infrastructure of transport whose individual vehicles or platooning vehicle units perform an autonomous "self-driving" without human intervention. The human driver becomes a passenger being driven by the vehicle in urban, rural and highways contexts. In addition, the autonomous vehicle is capable of communicating and coordinating its dynamic and static behaviour with other vehicles, with road infrastructures and with service providers via internet connectivity (to perform speed control, stops, avoid collisions, change lines, take directions, exchange data for mobile services, etc.). This transition is at the down of its development and deployment.

CCAM is a new concept of mobility that promises to bring redical increases in road safety and efficiency of the road transport system. The policy aim is to increase the overal efficienty of the mobility system. All inefficiencies and traffic accidents have a direct impact on the energy efficiency of the transport and mobility system. These being caused by destruction of mobility assets (destruciton of vehicles that must be replaced), damages in roads and congestion. All these undersired ineficiencies are to be ammeliorated by the advent of CCAM in conjunctions with the deployment of electrification of the vehicle park.

The transition to CCAM is primarly promoted by automotive and digital tech firms with the support of national and suppranational institutions. In Europe the most important promoter and supporter of the transition is the European CCAM Partnership. The CCAM partnership vision is to "… is to make Europe a world leader in the deployment of connected and automated mobility, making a step-change in Europe in bringing down the number of road fatalities, reducing harmful emissions from transport and reducing congestion. The deployment of driverless mobility – when fully integrated in the whole transport system and accompanied by the right support measures and synergies between driverless mobility and decarbonisation measures – is expected to contribute significantly to achieving these key societal objectives. Ultimately this is expected to lead to achieving the so-called Vision Zero, i.e. no road fatalities on European roads by 2050".[1]

[1] White Paper: Roadmap to a Single European Transport Area, COM(2011) 144. This vision from 2011 remains in the new European Commission communication "on the road to automated mobility: an EU strategy for mobility of the future", COM (2018) 283 final, Brussels 15.05.2018.

Many new vehicles are already connected with cellular technologies and all new cars (EVs and internal combustion) are expected to have integrated the capability for internet connection by 2022[2]. Such connectivity will enable fast access to information on traffic conditions ahead (e.g. accidents, roadworks, environmental conditions), it also will allow for large scale fleet data to be gathered by public authorities, such as anonymised real-life average fuel/energy consumption for the whole vehicle park in a given region or real-time traffic conditions.

The CCAM technology that is attributed to the vehicle is actually a technological system that requires a dynamic interaction with its surroundings. The vehicle autonomous features are enabled primarily by the vehicle onboard system complemented the with access to telecommunication infrastructures. Such infrastructures include primarily internet, satellite geolocation and data servers and corresponding data analytics (often with artificial intelligence). Such technologies are intrinsically linked to the advance of electrification of the vehicle park and its recharging infrastructure. All these technologies are evolving fast but the CCAM concept is still in the early stages of what we could call autonomy. Autonomous driving is still in the early stages of development. The level of autonomy has been defined in five levels of driving automation by the SAE Organisation, this is displayed in the Table 1 below.

Table 1 Vehicles automation levels

L1	L2	L3	L4	L5
Feet off	Hands off	Eyes off	Minds off	Driver less
2000s	2010s	Year 2020s	2030s	2040s

Source: based on SAE International (SAE, 2016)[3]

In the automation scale currently the automation levels L1 and L2 are fully developed and deployed in vehicles available for mass consumption. Levels three and above are still in development with vehicles L3 scheduled to enter the market in 2020 decade. Currently the technology is being developed and tested in European roads. L4 and L5 remain in the future.

Key objectives of the European CCAM transition include: 1) Increasing safety in road transport; 2) Reducing negative impacts from road transport on environment; 3) Ensuring inclusive mobility and goods access for all; 4) Strengthening competitiveness of European industries and 5) Capitalising knowledge to accelerate development and

[2] PwC, The 2017 Strategy & Digital report.

[3] Levels of automated driving according to SAE J3016. www.SAE.org, Society of Automotive Engineers levels see: http://articles.sae.org/13573/

deployment of CCAM solutions. This transition goes hand-in-hand with the electrification of the vehicle park as CCAM is to be operating in an electric vehicle platform. This creates challenges of transforming the vehicle in the "new smart phone" where software apparently rules the character of business models and the main motive of use.

The transition early stage is envisioned to be deployed in three phases:

- Phase 1 (2021- 2024) aiming to develop the building blocks of the transition. This includes vehicle and infrastructure technologies, key enables, validation methods the safety of functioning systems and methods to engage users and citizens.
- Phase 2 (2025 – 2027) is dedicated to advance the operational environments and when possible implement large scale demonstration projects, and advance the technology (TRL) for implementation in the final phase of the partnership.
- Phase 3 (2028 - 2030) will be oriented to promote and support the large upscaling of demonstration across Europe via trials in Living laboratories including users of vehicles in different contexts.

Given the complexities of the technological development (vehicle, telecommunications, cybersecurity, road and recharging infrastructures and the regulatory framework to guide the transition) the participation of the European citizenry has been absent. Despite this it is clear the transition cannot succeed without the engagement and acceptance of the autonomous vehicle by citizens. There is a great interest to understand the best form to engage citizens. This study report aims to contribute to such aim specially in the preparation of the deployment of Phase 3 of the CCAM transition.

1.2 Relevant actor and policy landscape

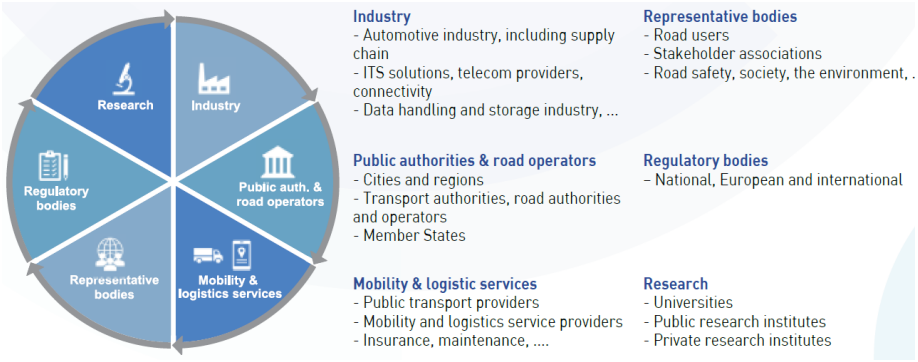
1.2.1 Relevant actors

As mentioned above the development and deployment of CCAM is an initiative that started within the automotive industry supported by policymakers. The technology as well as its regulatory framework are the early stages of development. This will become more clear when outlining the vision and objectives of the CCAM partnership. This partnership was formally established in 2021 as an international not-for-profit organisation. Currently the CCAM Association represents the private side of the CCAM Partnership, including more than 180 business entities and innovation stakeholders involved in the connected, cooperative and automated mobility field.[4] The representation of different sectors in the partnership is matched with the participation of several European and national institutions that participate in the development of

[4] CCAM - Members

strategies, policy and regulatory framework, co-funding research, as well as facilitating standards, piloting technologies and infrastructures .

Figure 1 European CCAM partnership stakeholders



Source: CCAM partnership

1.2.2 Policy landscape

The policy framework that supports the development and deployment of CCAM encompasses a very diverse set of topics. Amongst the most salient are the safety of the passenger, vehicle reliability of the concerning performance and safety, road infrastructures, telecommunication and data flows infrastructures that enable connectivity between vehicles and the context, and the environmental performance of such system. The overall regulatory framework is guided by two major European strategic policy documents:

- On the road to automated mobility: An EU strategy for mobility of the future, COM (2016) 766.[5]
- A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility, COM(2018) 283.[6]

The current European framework leads the way in setting the major guidelines for the transposition of European directives that give support to the energy and mobility single market. These orientation documents are supported by a complex set of regulations across different domains cutting across the mobility and energy. Amongst topic covered are: road infrastructure, data connectivity, cybersecurity, operational safety and certification, and climate change adaptation. Such regulatory framework is briefly sketched below.

[5] EUR-Lex - 52018DC0283 - EN - EUR-Lex (europa.eu)

[6] EUR-Lex - 52016DC0766 - EN - EUR-Lex (europa.eu)

Climate change adaptation

Running in parallel and sometimes preceding the CCAM initiatives related to safe and intelligent mobility in Europe, there are five large policy initiatives that are pillars supporting climate change resilience and adaptation. These are: 1) The CO2 emission performance standards for cars and vans: 2) The European emissions trading system; 3) The social climate fund; 4) The effort sharing regulation and 5) The regulation of land use land-use change and forestry. These pillars supporting the energy transition are briefly outlined below.

CO2 emission performance standards for cars and vans: The Council agreed to raise the targets for reducing CO2 emissions for new cars and new vans by 2030 to 55% instead for cars and to 50% for vans.[7] The Council also agreed to introduce a 100% CO2 emissions reduction target by 2035 for new cars and vans. Enabling drivers to recharge their vehicles across the member states will be ensured by the related revision of the deployment of an alternative fuels infrastructure (AFIR). The European Council agreed to put an end to the regulatory incentive mechanism for zero- and low-emission vehicles (ZLEV) as of 2030. The proposal of the reduction of CO2 emissions in transport vehicles (in this case cars) is part of a broader number of policy initiatives aiming to reduce emissions and their societal impacts. Amongst other measures that accompany the phasing out of ICE car include the following:

EU emissions trading system: The EU Emissions Trading System (ETS) is a carbon market based on a system of cap-and-trade of emission allowances for energy-intensive industries and the power generation sector. [8] The Council agreed to keep the overall ambition of 61% of emissions reductions by 2030 in the sectors covered by the EU ETS, proposed the Commission.

Social climate fund (SCF): The Council agreed to establish a SCF to support vulnerable households, micro-enterprises and transport users to support the creation of an emissions trading system for the buildings and road transport sectors.[9] The SCF would be established over the period 2027-2032, to coincide with the entry into force of

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[7] EU Council (2022) REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition. Dossier interinstitutional: 2021/0197 (COD), Council of the European Union, 30 June 2022.

[8] EU Council (2021) Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. interinstitutional File: 2021/0211(COD)

[9] EU Council (2022) Proposal for a Regulation of the European Parliament and of the Council establishing a Social Climate Fund. Dossier interinstitutional: 2021/0206(COD). Council of the European Union, Brussels, 20 June 2022

the ETS for the buildings and road transport sectors Each member state would submit to the Commission a CSF containing a set of measures and investments to address the impact of carbon ricing on vulnerable citizens. The fund will provide financial support to member states to finance the measures and investments identified in their plans, to increase the energy efficiency of buildings, the renovation of buildings, the decarbonisation of heating and air-conditioning in buildings and the uptake of zero-emission and low-emission mobility and transport, including measures providing direct income support in a temporary and limited manner.

Effort sharing regulation: The Council agreed to an EU-level greenhouse gas emissions reduction target of 40% compared to 2005, for the sectors not covered by the ETS, namely domestic maritime transport, agriculture, waste and small industries.[10]

Land use land-use change and forestry (LULUCF)**:** The LULUCF sector covers the use of soils, trees, plants, biomass and timber. Emissions and absorptions generated by the LULUCF sector are taken into account in the EU's overall 2030 target.[11]

The measures above (general approaches) outlined above are key legislative proposals that are pillars of the 'Fit for 55' package proposed by the European Commission on the summer of 2021 as part of the European Green Deal. The Fit for '55' package includes 13 specific measures aiming to support the European Union to tackle greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels and to achieve climate neutrality in 2050.

Ensuring infrastructure for connectivity

The Commission has set in motion a number of actions to support and promote the deployment of connectivity infrastructure and services in the support of automated vehicles with the adoption of strategies for the pillars supporting the deployment of CCAM across Europe for the connectivity aspects. These initiatives include:

- Standardisation Strategy[12]
- The 5th generation of communication networks ("5G")[13];
- Cooperative Intelligent Transport Systems[14];
- The Space Strategy[15];

[10] European Council proposition of Shared efforts on reduction of CO2 emissions. Dossier interinstitutional: 2021/0200(COD) Brussel 29 June 2022.

[11] European Council proposition of a regulation on the land use land-use change and forestry. Dossier interinstitutional: 2021/0201(COD). Brussels, 29 June 2022

[12] https://ec.europa.eu/docsroom/documents/48598

[13] Communication from the European Commission "5G for Europe: An Action Plan", COM(2016) 588.

[14] Communication from the European Commission on Cooperative Intelligent Transport Systems, COM(2016) 766.

[15] Communication from the European Commission "Space Strategy for Europe", COM(2016) 705.

- Artificial intelligence[16]

Data flows and cybersecurity

Digital technologies are transforming many areas of economic activity in different sectors. The generation, storage, transmission, trading and analytics of data have generated a number of new regulations in recent years. The full effect on privacy, cybersecurity, new services and business models remains to be seen in the medium and long term. In general, the advent of new directives has to be adopted and implemented at the European Member States. The most well-known regulation on data flows is the General Data Protection Regulation (GDPR) that was approved by the European Parliament in 2016.[17] Despite that it was published in 2016 little is known of it from the common European citizen and its implications for privacy and data protections. In addition to the GDPR, there are a number of proposals to regulate data flows, data analytics and the services associated to these across different domains. These new initiatives that hold relation with and will be affecting the deployment of CCAM over the next decade are listed below.

- Proposed Digital Markets Act (DMA)[18]
- Proposed Digital Services Act (DSA)[19]
- Proposal for a Regulation on harmonised rules on fair access to and use of data (Data Act)[20]
- Proposal for a Data Governance Act[21]
- Proposal for a European Digital Identity (eIDAS 2)[22]
- Proposal for a Regulation laying down harmonised rules on artificial intelligence[23]
- Proposal for a Regulation establishing the Union Secure Connectivity Programme for the period 2023-2027[24]
- Proposal for a Geo-Blocking Regulations[25]
- The EU's Regulation on Promoting Fairness and Transparency for Business Users of Online Intermediation Services (the Platform to Business Regulation or P2BR) including Guidelines on the "ranking transparency" under the P2BR.

[16] COM(2018) 237.

[17] General Data Protection Regulation (GDPR) – Official Legal Text (gdpr-info.eu)

[18] https://eur-lex.europa.eu/legal-content/en/TXT/?qid=1608116887159&uri=COM%3A2020%3A842%3AFIN

[19] https://eur-lex.europa.eu/legal-content/en/TXT/?qid=1608117147218&uri=COM%3A2020%3A825%3AFIN

[20] https://digital-strategy.ec.europa.eu/news-redirect/736379

[21] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0767

[22] https://digital-strategy.ec.europa.eu/news-redirect/712464

[23] https://digital-strategy.ec.europa.eu/news-redirect/709090

[24] https://ec.europa.eu/info/sites/default/files/proposal_regulation_union_secure_connectivity_programme.pdf

[25] https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_15_5704/IP_15_5704_EN.pdf

- Proposed e-Privacy regulation[26]
- Cybersecurity Act[27]
- the "European Electronic Communications Code" (the "EECC")

Operational safety of autonomous vehicles

Key to ensure safety and reliability of CCAM are the protocols to measure and assess the performance of new vehicle systems. These are protocols that have been developed with the multilateral cooperation of automotive, road and transport authorities. Key to the operational safety of new vehicles is the Directive 2010/40/EU on the Framework for the Deployment of Intelligent Transport Systems in the Field of Road Transport and for Interfaces with Other Modes of Transport (ITS Directive). This directive is complemented by three other that ensure the standardisation of testing protocols, driver licences and product liabilities.

- Regulation (EU) 2018/858 on the Approval of Motor Vehicles
- Directive 2006/126/EC on Driving Licences
- Directive 85/374/EEC on Product Liability

At a National level, vehicle requirements, vehicle identification and registration, exemption legislation and procedures, road safety, traffic rules or driving licenses are regulated both by EU and/ or national standards. In this context, each country has its own specific regulatory framework for automated driving purposes. Given that the level of automation is generally level three for most advanced systems, vehicles manufacturing companies and research organisations developing these technologies are further developing subsystems required in the vehicles. Autonomous vehicles require extensive testing before being allowed to be manufactured and upscaling sales for road use.

Manufacturers and brands are required to comply with European automotive and road safety regulations. In addition, they are required to consider national regulations of several European countries in order to run tests involving connected and automated vehicles. Regarding open road driving activities for testing automated driving functions, it is general practice in several European countries to require additional information, in order to allow the deployment of Field Operational Tests nationally.

[26] https://digital-strategy.ec.europa.eu/en/library/proposal-regulation-privacy-and-electronic-communications

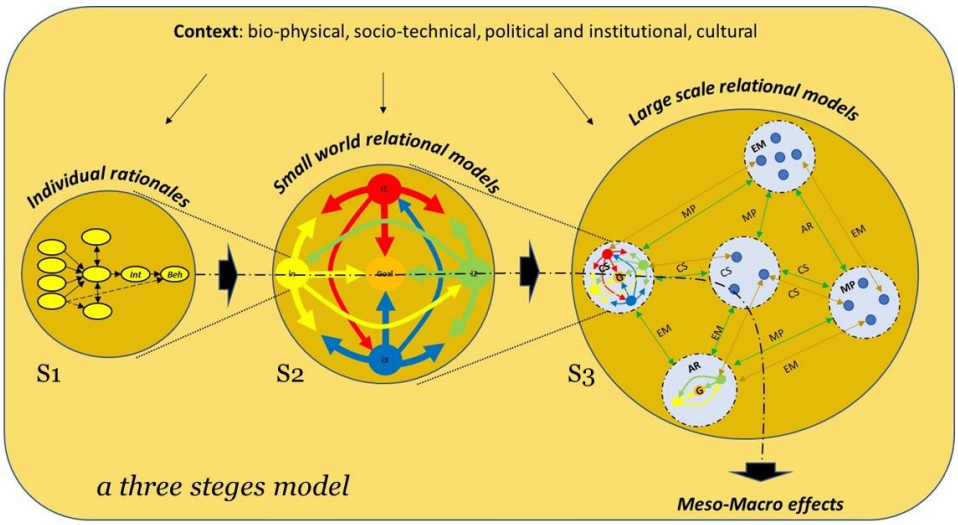
[27] https://eur-lex.europa.eu/eli/reg/2019/881/oj

1.3 Case study research design

1.3.1 Summary research framework on citizen engagement

This case study report aims to test the stage one of the theoretical framework developed in D1.1 concerning the structure of the motivations of citizens to engage in green energy transition actions (GRETA) looking into CCAM as an experiment to test the major proposition of the framework (proposition 1 outlined below).[28] The stage one model addressed the rationales of individual citizens to engage in CCAM.

Figure 2 Citizen engagement structure and dynamics: 3 stage model



Source: Montalvo et al., 2022[29]

According to the framework developed in deliverable D1.1the engagement in the development, adoption, and use of green energy and practices depends on the following:

(OUTCOMES [OUT]) the extent to which the engagement in GRETA (in specific behaviours) is regarded positive or negative by the civil society[30], governments, and the private sector. Outcomes that affect the actors themselves, society, the

[28] Montalvo, C., Schlindwein, L., Ruggieri, B., Kantel, A. (2021). Framework for research on energy citizenship emergence structure and dynamics. D1.1 of the Horizon 2020 project GRETA, EC grant agreement no 101022317, The Hague, The Netherlands.

[29] Montalvo et al., (2021) Op cit.

[30] For matters of simplification of the presentation and discourse in this report we use the term "citizens" to encompass consumers, prosumers, prosumagers, participants in protests and movements and energy communities. We will refer to three type of actors: citizens, policymakers and businesses.

environment and climate change. These outcomes will be clustered in social, environmental and economic outcomes;

(Social NORMS [SN]) the extent to which citizens, the policy and regulatory environments, and the private sector support the uptake of practices and solutions supporting GRETA;

(AGENCY [AG]) the level of agency and resources available for the implementation of GRETA for each of the actors considered in the case studies:

For citizens' agency and resources to engage in GRETA (income, knowledge, availability of time, etc.);

(RELATIONAL MODEL [RM]) the nature and congruence (between dominant and desired) of the social relational models that guide and determine the interaction between citizens, policymakers, and businesses.

(EMOTION [EM]) the emotional state generated by the assessment of outcomes, pressures, agency, and dominant relational model serves as catalyser of engagement in specific behaviours supporting GRETA

The linkages between the above briefly defined constructs are outlined and made explicit regarding their relationship with engagement in GRETA. In summary, the proposed set of hypotheses aim to test that the individual citizen engagement arises from internal and external sources. Internally the interaction of the individuals own held values, agency, goals, and intentions, all play a certain role in influencing engagement. Similarly the perception and experience of the external determinants like influences from others, the context where the engagement takes place and the institutions moderating individuals' actions supporting the green energy transition. The definitions and linkages described above also make explicit that the behaviour at the individual citizen level has emergent features like collective behaviour.

PROPOSITION 1: Converging to common actions and social goals (in this case GRETA, i.e., Green Energy Transition Actions) is contingent on the collective expectations and on perceptions of different actors (e.g., citizens, policymakers and business entities) regarding the outcomes, agency, norms and values, emotions as well as the rules of relations and interdependence between the actors. This proposition is tested for the model stage one **(S_1)** by falsifying the following six hypotheses:

H1: The citizens engagement (ENG) in GRETA can be explained in terms of the citizens' outcomes arising from the engagement in GRETA (OUT), the dominant social norm to engage in GRETA (SN), the level of agency exerted on GRETA (AG) as perceived by citizens, relational model mediating interactions with other actors (RM), and the emotional state of citizens.

H2: All items included in each of the scales measuring ENG, OUT, SN, AG, RM and EM have a high internal cohesiveness enabling a reliable measurement and scaling of the concepts underlying the construct.

H3: The structure of the quantitative data matches the structure of the relations defined in H1: ENG= ENG(OUT, SN, AG, RM, EM).

H4: A confirmatory factor analysis on the empirical data converges to a solution of six dimensions (two cognitive, normative, instrumental, relational and emotional) confirming the structure of the model used to collect data.

H5: Congruence and alignment of relational models has a significant positive effect on the individual and collective engagement in GRETA.

H6: Dissonance between relational models has a significant negative effect on the individual and collective engagement in GRETA.

1.3.2 Eliciting drivers and motivations of citizens and other actors

The identification of drivers and motivations to for citizens to engage in CCAM draw from the general wisdom found in recent literature on autonomous driving and consumer acceptance and complementary interviews that followed the protocol outlined in GRETA deliverable D1.3.[31] The application of the interviews guidelines to CCAM required a good definition of the behaviours and actions that citizens would perform while engaging in "energy citizenship" in relation to CCAM. The definition of such behaviour followed the guidelines provided in the GRETA deliverable 1.3 as well.[32] After such behaviour was defined potential interviewees were contacted to elicit levels of engagement and motivational factors. This activity followed D.13 as well.

1.3.3 Questionnaire

The questionnaire used to gather data to identify, quantify and validate drivers and motivational factors followed the behavioural model for citizen engagement proposed in GRETA Deliverable 1.1.[33] The questionnaire included, in addition to socio-demographic questions, seven scales to assess each of the main constructs of the behavioural model (i.e., engagement, outcomes, social norm, agency, relational model shift, and emotion). This questionnaire was elaborated as an standardised measurement instrument to be applied in other case studies. The questionnaire for CCAM used in this case study is included in Annex 1.

[31] Montalvo, C.(2022). D1.3 Guidelines and protocols for GRETA case study implementation of the Horizon 2020 project GRETA, EC grant agreement no 101022317, The Hague, The Netherlands.

[32] Montalvo, C. (2022) op. cit.

[33] Montalvo, C., Schlindwein, L., Ruggieri, B., Kantel, A. (2021). Framework for research on energy citizenship emergence structure and dynamics. D1.1 of the Horizon 2020 project GRETA, EC grant agreement no 101022317, The Hague, The Netherlands.

1.3.4 Survey

In order to gather quantitative data on the level of engagement in CCAM as well as motivational drivers enabling and barriers that might hamper the engagement in CCAM a survey was launched in.[34]

The target sample is 10,000 individual responses split into three separate groups:

- citizens (i.e., residential energy users) - 90 % of the sample,
- businesses - 5 % of the sample,
- public policy makers - 5 % of the sample.

The survey is conducted in sixteen European countries:

- Northern Europe: Finland, Netherlands, Ireland, Denmark
- Southern Europe: Greece, Italy, Spain and Portugal
- Eastern Europe: Czech Republic, Hungary, Poland and Romania
- Northern Europe: Austria, France, Belgium and Germany

The survey included a panel of potential respondents considering age, gender and income as demographics to obtain a European representative sample for the countries covered. The survey was launch in the summer of 2022 and the panel rendered 3036 usable questionnaires. The survey participants responded questions with closed multiple response option. In the CCAM case study 3039 responded complete questionnaire. Out of such respondents 908 responded to some of the questions in the items-scale with the option "I don't know". This produced a highly skewed distribution of response and this limited the analysis with central trends methods that assume normal distribution. As a consequence of this, 908 respondents were screened per construct and for all relevant items with the answer "I don't know" were removed from some of the analyses. This rendered a sample of 2128 respondents included in the correlation and regression analyses.

[34] Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Romania and Spain.

2 Research results

2.1 Case study results

CCAM has received considerable attention over the last decade.[35] In particular the attention given to the acceptance of the automated vehicles has increased over the last five years. Despite the early stages of the technology for L3 and above the studies available give the impression that the adoption is imminent. It calls the attention that enquires focus on acceptance and not in the actual engagement and use of the technology by citizens, the conceptualization of the user remains as consumer. Despite such differences the available in-depth studies have provided much valuable information that guided the qualitative stage of the CCAM study in GRETA. Despite of the great number of factors identified in the literature the most common factors identified are just a few important ones. This is specially the case when a large proportion of the citizenry holds little knowledge and understanding about CCAM to make a good assessment of its performance implications for the individual citizen, society and the environment. This fact is confirmed with the European survey data as will be shown in further sections of this report. In agreement with the report of the G7, despite the large variation on factors identified affecting acceptance of automated vehicles, there are a number of factors that are recurrent across the literature.[36] These include the following:

- Fluctuations and blowbacks in acceptance are still dependent on serious and visible accidents
- Acceptance is expected to be higher in the long-term than for present adoption
- Trust is key factor influencing public acceptance
- Experiencing either an automated or autonomous transport system increases acceptance
- Main suitable target in willingness-to-purchase are young men with high income
- Less informed people about AVs are the main opponent to it, and vice versa
- adoption is directly linked to a reduction of the AVs price over time

It worth mentioning here that the literature on automated driving has focused primarily on acceptance, i.e., a positive attitude and willingness to buy an AV with automated features. Is less about actually engaging with automated vehicles as is the focus of this GRETA case study in CCAM. In addition, invariably the focus of attention

[35] For an early review see: Becker, F., and Axhausen, K. W. (2017). Literature review on surveys investigating the acceptance of automated vehicles. Transportation, 44(6), 1293-1306.

[36] G7 (2019) Autonomous vehicle acceptance : overview of recent studies and research. Report of the G7 expert group on automated and connected driving to the French Ministry of the Ecologic and Solidary Transition. DGITM/SAGS/EP, Paris

of the literature on acceptance leaves out of the enquire the roles and engagement of other social actors.[37] As shown below in this section, in our case study we also enquired upon the perception and position of government and business regarding CCAM development and deployment. In the following we present in a synthetic form the main results of this qualitative stage of the enquire.

In the following sections in this chapter a number of summary tables with elicited factors that affect the actual engagement of citizens in CCAM will be described. Following the model proposed by Montalvo et al., these factors are organised in three large groups, expected outcomes arising from the engagement in CCAM, the social norm and social support perceived by citizens and the capacity and resources needed for the actual engagement in CCAM. The elicitation of the drivers and barriers followed a common interview guide that was used in all case studies in the GRETA project (See deliverable D.1.3 for the interview guide). A large variety of drivers was that might affect the engagement in energy citizenship were elicited across all case studies in all three different type of actors interviewed (citizens, policymakers and businesses actors). These drivers where organised according to their common latent meaning. This variation is clarified and organised in comparative tables in the following sections.

2.1.1 Outcomes associated with engaging in CCAM

The expected outcomes elicited were organised in few common concepts that capture the latent value across stakeholders. These are safety effects, safety, environmental effects, costs of complying with regulations (EVs vs internal combustion), effect on convenience and comfort, the individual household economy, the autonomy, effect on community participation, and privacy.

Table 2. Elicited positive and negative outcomes of engaging in CCAM

Citizens	Policy makers	Business
Positive		
Environmental: Traffic jams better managed, less time in roads, less CO2, use as energy storage in car when grid cannot take the charge of home solar panels; less noise	*Environmental* Environmental CO2 reduction, noise reduction, smooth traffic reduces energy, enables vehicle to greed energy exchanges	*Environmental* Aggregated energy efficiency, environmental benefits, citizens will be environmentally friendly, enables vehicle to greed energy exchanges

[37] Cfr. Synthetic review of the literature in Annex 2

Citizens	Policy makers	Business
Personal benefits: comfort & convenience less maintenance; Relaxed driving Time to do other activities in car other than driving	*Social and economic* Higher inclusivity for people that cannot drive; Inclusive mobility (for elderly, disabled people and remote users, etc.)	**Social and economic:** **social**: more functionalities for the same price; Higher inclusivity for people that cannot drive; **Economic**: More profitable: Why, the cars offer for now higher profit margin for example at a L4 automation; or more functionalities for the same price; promise more sales; pre-empting competition from other manufacturers; they could become a platform for other services or vertical integration like the smart phone (business spill-overs), like apps to find rechargeable infrastructures, follow the concept of supporting Apps, like valet car
Safety Better safety features, feels like supporting,	*Safety* Safety increases and safer car (for example limiting speed like Volvo);	*Safety* Less accidents in the vehicle park across users; market segmentation upon safety thresholds (some cars start automation at 40kmh while others at 100kmh)
	Political motivations: score good points, remembered for good things, party. For example jobs, strengthening industry, international competitive positions,	*Political motivations:* Pre-empting upcoming regulatory issues with access to city centres for example; more means for project differentiation with wider range of differentiation; being part of the digital community is good for reputation;
Economic: Higher gas price in future Very high cost of purchase; Lower operational and maintenance costs; Access to lower energy tariffs and prevents CO2 regulations	*Economic:* Support national industry for international competitive positions, technology sovereignty;	*Economic:* don't miss the bandwagon of autonomous driving; might create new type of business services, more profitable: Why, the cars offer for now higher profit margin for example at a L4 automation; or promise more sales; pre-empting competition from other manufacturers; they could become a platform for other services or vertical integration like the smart phone (business spillovers), like apps to find rechargeable infrastructures, follow the concept of supporting Apps, like valet car
	Negative	
Environmental: Battery life-span and recyclability Battery hazards,	**Environmental:** Battery life-span and recyclability Battery hazards,	**Environmental:** Maturity of battery technology,
Safety and security cybersecurity, risk of privacy	*Safety and security* Undesired death by faulty automated cars performance**;** cybersecurity attacks on data assets; risk to privacy of citizens; risk on	*Safety and security* potential liabilities to the brand if damages are caused by malfunction of car; vulnerability to cybersecurity risks;

Citizens	Policy makers	Business
	companies and regulatory agency data assets	
Economic and financial Too expensive Battery replacement is half the price of the car Battery reliability and lifetime, Costly data services;	*Economic and financial* Risk of liability Certification for faulty technology - risk for authorities; Data-cyber risks, reliability of ICT, data tracking and privacy Road authorities at member state level (costly for them, need to invest in infrastructures)	*Economic and financial* risky investment in unmature battery technology for range and recyclability, potential failures of early generation vehicles (the car causes accidents, kill people); lack of quality of data flows; risk of liability Certification for faulty technology - risk for suppliers
Personal: Range limited Limited availability of recharging facilities (urban vs rural)	*Personal:* Not being taken seriously enough by parties :	*Personal:* Individual companies or CEO's potential liabilities, brand damage if they go early with CCAM that is not well developed/mature enough; potential recall due to minor failures; lack of support of more players in the project delivery (e.g., telecommunication systems not ready easily overloaded broadband) more stakeholders involved, the complexity in the system can cause failures that is not due to vehicle but is experienced in the vehicle as a vehicle problem (but the problem is the supporting system for example, information provided by communications like calculating the speed (driving in the wrong speed), calculating the route, traffic information, roadworks, even weather) all of these depends of services flowing into the car;

2.1.2 Social norms associated with engaging CCAM

Table 3. Social norms associated with engaging CCAM

Citizens	Policymakers	Business
Intrinsic motivation: No intrinsic motivation or scepticism about natural gas-free plans Openness to renewal	*Intrinsic motivation:* Enthusiasm and perseverance Mandate to support sustainability of transport, Common goal	*Intrinsic motivation:* Market differentiation, higher profit margins, industry leadership
Experience of peers (i.e., family, friends, colleagues) Experience of a like-minded individual that accepts CCAM	Experience of peers (i.e., other local energy initiatives) Against it: labour unions drivers; motorcycles manufactures could be against it; Political and reputational pressure to adopt green energies; Lobbying from member states to the European Institutions; to allow autonomous cars at the national level is necessary to have approval at the EU level; vehicle approval is done	Experience of peers (i.e., other municipalities) Logistics companies could be pro or against Lobbying from mobility platforms (Uber, Lyft, etc); ; logistics companies could be pro or against;

Citizens	Policymakers	Business
	at the EU level, so pressure will be felt at the EU level; Lobbying from mobility platforms (Uber, Lyft, etc); ; logistics companies could be pro or against; User organisations Stakeholder pressure and consideration, resistance to legislation User organisations Stakeholder pressure and consideration, resistance to legislation; lobbying from industry to support and certify (manufacturers)	

2.1.3 Agency associated with engaging in CCAM

Table 4 Agency associated with engaging in CCAM

Homeowners	Policymakers	Business
Time: No time to participate in lobbying or campaigning pro or against CCAM; Battery requires long recharging time (time wasted)	*Time*: Timing and commitment to participate in CCAM is linked to political agendas of incumbent government administrations	*Time*: Long time horizon of development linked to technological and financial risks
Trust Trust in municipality/ government/ suppliers/ solutions: Trust on Technology/privacy/suppliers	*Trust*: Trust in municipalities, Dutch government and suppliers	Trust of citizens (local energy initiatives/ homeowners), government and suppliers Trust on the provider of the information, no control on quality of information services flowing into the car
Financial: Cost of electric autonomous cars/can't pay for it Cover cost for new electric installation at home (400v) for car recharging	*Financial :* Insufficient (structural) funding Road authorities at member state level (costly for them, need to invest in infrastructures); enacting subsidies for cars (CCAM)? Via tax exceptions	*Financial:* Business are muddling through with heavy investments in supporting technologies Major brands are heavily investing in CCAM level 3 [what is stopping CCAM?: for level 4 automated driving cost are too high to be economically viable
Knowledge: Limited understanding of technology (automation levels) Lack of knowledge on the benefits of CCAM	*Knowledge:* Knowledge of technical interventions Varieties of road infrastructures, different traffic signs, traffic lights operate differently (move towards harmonisation), traffic rules are different; cybersecurity issues; knowledge on traffic rules changes; knowledge on telecom and networks Understand citizens acceptance, the evolution of regulations across MS	*Knowledge:* Automotive engineering is old school and need to understand sensor technologies, existing telecommunication standards, decision making algorithms in the car, cybersecurity system challenges (also for internal combustion engines and EVs); knowledge in all subsystem key components to outsource from suppliers; need to know traffic rules and how these are changing; get involved in the design of standardisation and regulation;

Homeowners	Policymakers	Business
	(approval of automated systems, security, etc.) ;	Understand user acceptance, the evolution of regulations (approval of automated systems, security, etc.) ;
Social network and cooperation Honest communication Personal approach Going along with initiatives Finding somebody to listen Nice and informative resident evenings No participation on public decisions related to deployment of CCAM	*Social network/ cooperation:* Differences in values and political agenda priorities between ministries might make cooperation difficult Do not finance but support R&D and testing technologies	*Social network and cooperation* Understand user acceptance, the evolution of regulations (approval of automated systems, security, etc.) ; need to know traffic rules and how these are changing; get involved in the design of standardisation and regulation; Strong participation on CCAM partnership. Collaboration is seen as a keystone to develop CCAM in Europe. Capacity to coordinate is high Cooperation reduces R&D+i investment risks;
Legacy systems: Existing vehicle Lack of recharging infrastructure at home Not aware of issues of lock in legacy systems in government and businesses	*Legacy systems:* Requirements of infrastructures; requirements of safety; enacting regulations to support CCAM Varieties of road infrastructures, different traffic signs, traffic lights operate differently (move towards harmonisation), traffic rules are different; cybersecurity issues; knowledge on traffic rules changes; knowledge on telecom and networks	*Legacy systems:* Infrastructure is not ready; dependency on public infrastructures; not adequate regulations and traffic rules; automated driving is possible but not allowed by regulation; developing interoperability technologies and standards is lengthy and costly public infrastructure of bad quality not supporting efficiently deployment of CCAM

The above factors were compared with other case studies in the GRETA project to identify the latent concept underlying the perception and reported drivers according to the method proposed in Deliverable 1.3. which is briefly outlined here:

The questionnaire design and structure to test the three stages model builds on the information gathered from interviews for the three actors of interest (citizens, policymakers and business), as described in D1.3. In summary, the questionnaire design was a process that started with the definitions of the behaviours that the actors would display if engaged in energy citizenship. This continued with the conduction of interviews and proceeds with the development of a matrix to analyse the variations and similarities across respondents that participated in the interviews. This step corresponds to the Tables 2 two 5 presented in the section above. This last step enabled to reduce information across the case studies into a manageable number of questions. The method followed is presented in a stylized form in Table 5 below.

Table 5 Method for synthesis of elicited factors into common latent meaning

Belief coding	Case study no.	Questions variation	Latent meaning (e.g., Agency)	Leading question
X1	1 - 6	Many	Knowledge	How would you assess regarding
X2	1 - 6	forms of	Economic resources	knowledge and resources to <<the
X3	1 - 6	expressing	Collaborative capacity	behaviour of interest>>? (high-low)
...	1 - 6	the same	Trust others and tech	
Xn	1 - 6	concept	Time availability	

Source: Montalvo 2022[38]

This process produced a number of standard question items for all constructs in the model that would be applied across the GRETA case studies. The resulting categories and full questionnaire are presented in Annex 1.

2.2 Multinational survey results

2.2.1 CCAM citizens engagement levels across EU countries

CCAM is an initiative for technological advances in vehicles, data connectivity and associated services that encapsulates a new form of mobility and is a radical shift in the way a vehicle is conceptualized. This new development is expected to have a strong impact in sustainability. As mentioned in the introduction CCAM is driven initially and primarily by business, vehicles manufacturers and digital industries. As this new development promises major source of industry renewal and enabler of new business models based on service rather than ownership. Policymakers and the European and national member state levels have so far being supportive of such initiative. The European Commission have helped to organise the activities and regulatory framework that will give support to the full deployment of CCAM in the EU. Given the level of CCAM development, i.e. level 3, the participation of citizens CCAM has been absent. This is due to the early stage of development, CCAM stage level three is expected to enter in the 2020's wide deployment of testing on the roads. As it stands now, for this decade, this does not include massive sales to consumers.

The participation of citizens is currently in the pre-deployment stages CCAM featured by the diffusion of EVs that serves as platform for CCAM. Such participation has been primarily engaging citizens with high income levels due to the high cost of electric vehicles. The participation and engagement of middle and low income citizens in the wide diffusion of EVs remain in the future. This is expected to increase during the

[38] Montalvo, C.(2022). Guidelines and protocols for GRETA case study implementation D1.3 of the Horizon 2020 project GRETA, EC grant agreement no 101022317, The Hague, The Netherlands.

2020's decade and take off after 2035 due to the banning of internal combustion engines sales in Europe.

The absence of citizens in the development strategy of CCAM is primarily due to requirements of the knowledge intensive discussions on different aspects of the technology, standards and regulatory framework required to enable CCAM.[39] In a nutshell citizens don't have the time, information or resources necessary to participate in the CCAM pre-deployment stage (for levels L3, L4 and L5 of automation). Given the above context it is expected that during the lifetime of GRETA and perhaps five years beyond many citizens will remain unaware while some be aware of the existence and details of CCAM and few will be engaged in the use of autonomous vehicles. In this sense the is not a "community of citizens engaged in the CCAM transition" as yet, like in other topics addressed in the GRETA project.

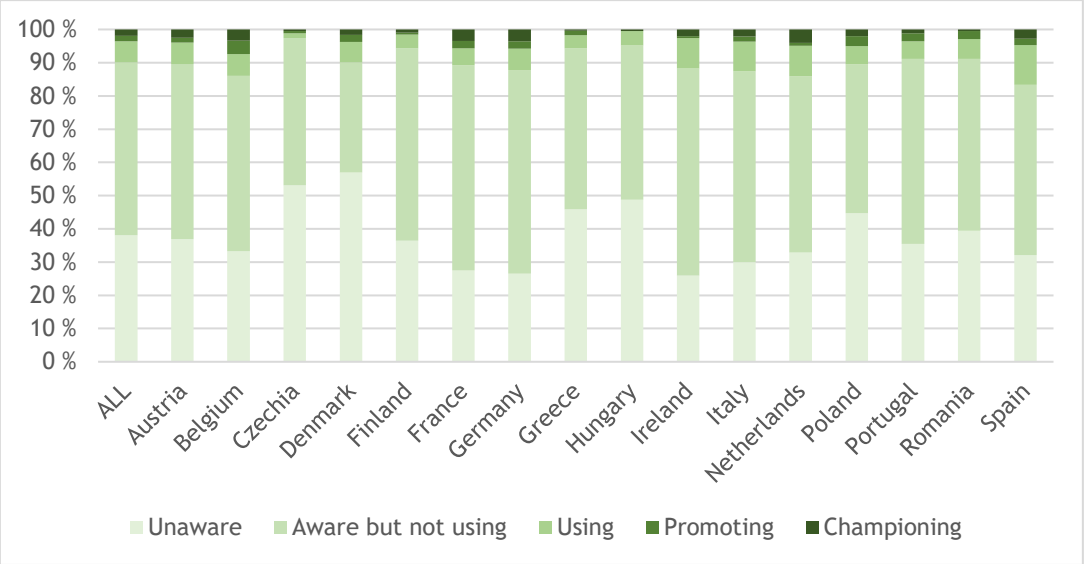
This is confirmed by the survey results on the level of engagement reported by citizens and depicted in Figure 3 below. An European average in the countries surveyed indicates that only 10% of respondents (lead users) are somehow engaged in the use, promotion or championing of autonomous self-driving vehicles.[40] This insight is aligned with the qualitative stage of the study whereby a large majority of interviewed citizens indicated to have little knowledge on the actual features and implications of automated vehicles and the levels of automation. These insights are at odds with the literature addressing the acceptance of autonomous driving that gives the impression that acceptance is increasing over the years (good attitudes and willingness to buy). The figure makes clear that, **for a large majority of European citizens, acceptance although a necessary condition for use is not sufficient to explain engagement in CCAM.**

Figure 3 makes clear that a large majority of Europeans that participated in the survey are not much aware of the advent and transformative relevance of the upcoming autonomous driving. In Denmark for example a whopping 53% of the respondents indicated not being aware of the features of an self-driving car while 33% indicated being aware but not using it. The trends of expected engagement are, according to the reported expected engagement within 5 and long term, expected to change positively but marginally not reaching higher engagement in about 85% of the respondents in the survey.

[39] Other factors like lack of time, resources and interest might play a role as well.

[40] (N=3036)

Figure 3 CCAM: Citizens engagement levels (EU Selected countries, N=3036)



The European average stays close to such numbers, whereby only 10% of the sample indicated to see themselves using, promoting or championing CCAM. This kind of finding is in stark contrast with the reports found in the literature of CCAM acceptance that indicate an increasing trend of acceptance.[41] The correlation analysis displayed in Table 6 below indicates that indeed the lower the age the lower the expected engagement in CCAM now and in the longer term.

Table 6 Correlation between CCAM engagement with age, income and education

	CCAM Engagement currently	CCAM_ENG five years	CCAM_ENG longer term	Age	Education
CCAM Engagement currently	--				
CCAM_ENG next five years	,340**	--			
CCAM_ENG longer term	,296**	,713**	--		
Age	-,188**	-,218**	-,203**	--	
Education level?	,115**	,109**	,114**	-,067**	--
Income [€]	,097**	,059**	0,038	-,055**	,119**

**. Correlation is significant at the 0.01 level (2-tailed). N=2128

The Figure 4 below indicates a proportional representation of the sample according to the age brackets used. With a 26% of the sample being under 35 years of age. It can be expected that given that fact that younger people tend to have a lower income, **this age bracket (18-35 years) could be expected to be less prone to engage in CCAM despite of having a good attitude towards it**.[42] Similarly, Table 6 indicates that levels of income

[41] A great deal of the literature available report findings from the U.S., Asia or Australia, fewer case studies in Europe were found.

[42] This assertion must be tested with the quantitative data! Correlation analysis age vs engagement.

and education are positively related with engagement in CCAM currently and in the longer term. Both demographic indicators are positively correlated between them while there is a negative correlation between levels of income and education. That is the younger the respondents the lower the level of education and the level of income.

The above implies that the development of any policy supporting the deployment and promotion of engagement in CCAM in younger citizens must consider education and income levels before considering any other factor. This is due to the fact that **income and education levels are a strong moderator of agency of citizens to engage in CCAM** and in any other behaviour supporting the energy transition.

Figure 4 CCAM: Age distribution (EU Selected countries, N=3036)

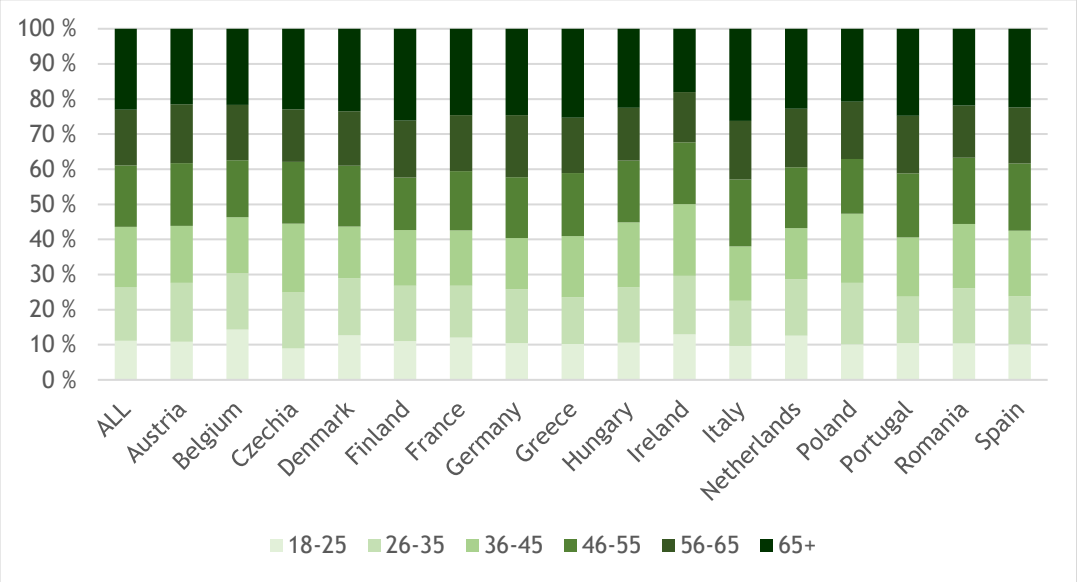
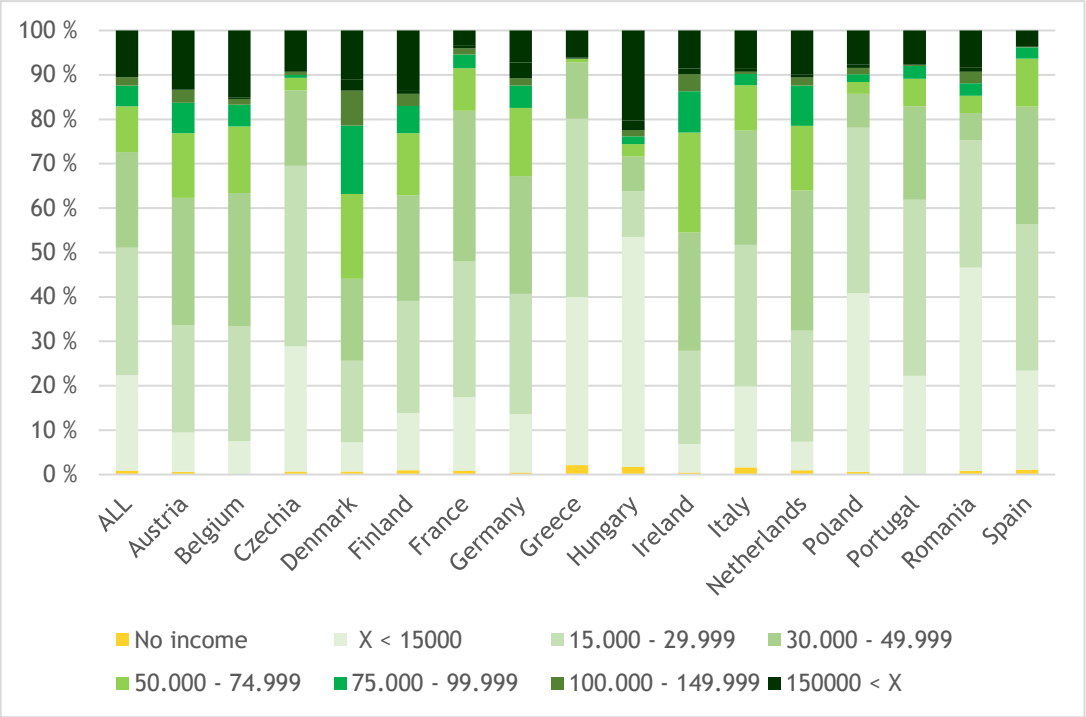


Figure 5 Income levels (EU Selected countries, N=3036)[43]



[43] annual mean net income [€] in the last year

3 Analysis

This section aims to present the trends identified with the help of the European survey. It also conducts the testing of hypotheses to validate empirically the behavioural model that guided the design of the empirical enquire into the determinants of the engagement in Energy citizenship. It addresses questions of reliability of measurements, the structure of the model used and its contend validity. All these tests are oriented to test the hypotheses H1 through H7. The last section explores hidden structural patterns that affect behavioural preferences on the level of engagement in CCAM that have direct implications for policy. In turn this will bring insights into the analysis of energy citizenship emergence and the energy transition.

3.1 Behaviour and goals per actor

The overarching societal goal of CCAM in the is to significantly contribute to reach zero deaths and zero CO_2 emissions in the use and deployment of road transport and mobility in Europe. These goals have an intrinsic effect in the energy efficiency of the European transport and mobility system. Achieving these goals depends on the development and deployment of autonomous cars in Europe. In order to contribute to reaching these overarching goals, European policy goals and actions aim to make this process inclusive, thus, this depends on the involvement of a number of stakeholders. In the project GRETA three major type of stakeholders were considered in the case study design and analysis.[44] In order to contribute to the higher level policy objectives mentioned above the citizens, policymakers and business agents engage in certain behaviours that support (or not) the policy goals. Below a number of behaviours that are different but complementary across stakeholders when thinking of the contribution and role of each stakeholder. These behaviours can be considered as traits that would be found in citizens that are aware or not in the concept of energy citizenship.

- **Citizens**: Purchase, lease, or co-own & share an autonomous electric vehicle (AEV) this year for myself, family, company, community.
- **Policymakers**: Enforce higher CO_2 standards for AEVs, inform consumers about AEVs, provide subsidies to consumers for purchasing AEVs starting in 2023 in the Netherlands (or Limburg); support suppliers in the development and commercialisation of AEVs.

[44] This report present results only for citizens. The research results of the trends and interaction dynamics between the three actors will be presented in other deliverables pertaining to WP4.

- **Suppliers**: Supply AEVs below price of regular cars next year, or offer no interest rate loans for AEV this year (or next year) in Europe.

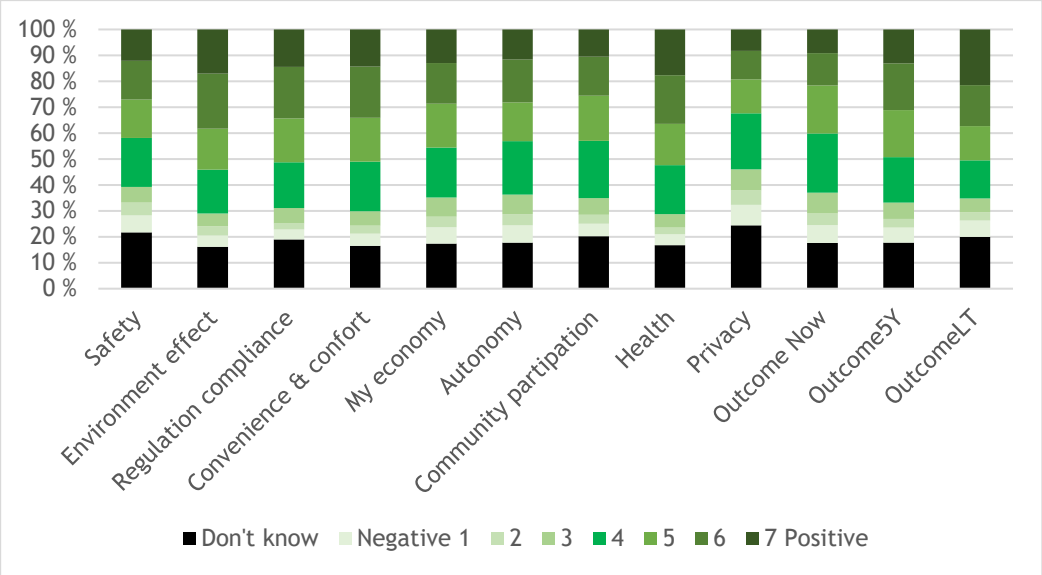
- **Suppliers**: Supply AEVs below price of regular cars next year, or Offer no interest rate loans for AEV this year (or next year).
- **Likely individual goal**: Increase shareholder value (profits and legitimacy)

Although the behaviours listed above are complementary to realise the objectives of CCAM and its contribution to the energy transitions the actual behaviours might respond to different motivations different from the energy transition. As seen in the previous chapter the motivations despite having perhaps the same label are conceptualised differently by each stakeholder. Their perspectives, priorities, resources and preferences might create mismatches despite of being highly complementary. In the following we abound in the perspective of citizens and how the perceive the potential outcomes of engaging in CCAM, the social support and pressures they might experience, the resources available and the most desirable relational social model that would support the transition to clean energy supported by CCAM.

3.2 Positive and negative outcomes associated with engaging in GRETA

As mentioned above the expected outcomes or effects that the engagement in the adoption and use of CCAM might bring for the individual household is assumed to have moderating role in the emergence of energy citizenship. The Figure 6 below shows the current trend in the survey sample addressing CCAM. In general, the trend leans to a very positive outlook of the expected outcomes. In average all item question show a frequency of response of 5 to 7 in a scale that varies from very negative to very positive. About 50% of the respondents in fall in this upper bracket of the graph in all of the items. With an about 10% falling into the very positive bracket. This last trend is aligned with the number of respondents that indicated to be using or championing CCAM (see Figure 3 above).

Figure 6 Expected outcomes of CCAM adoption (EU Selected countries, N=3036)

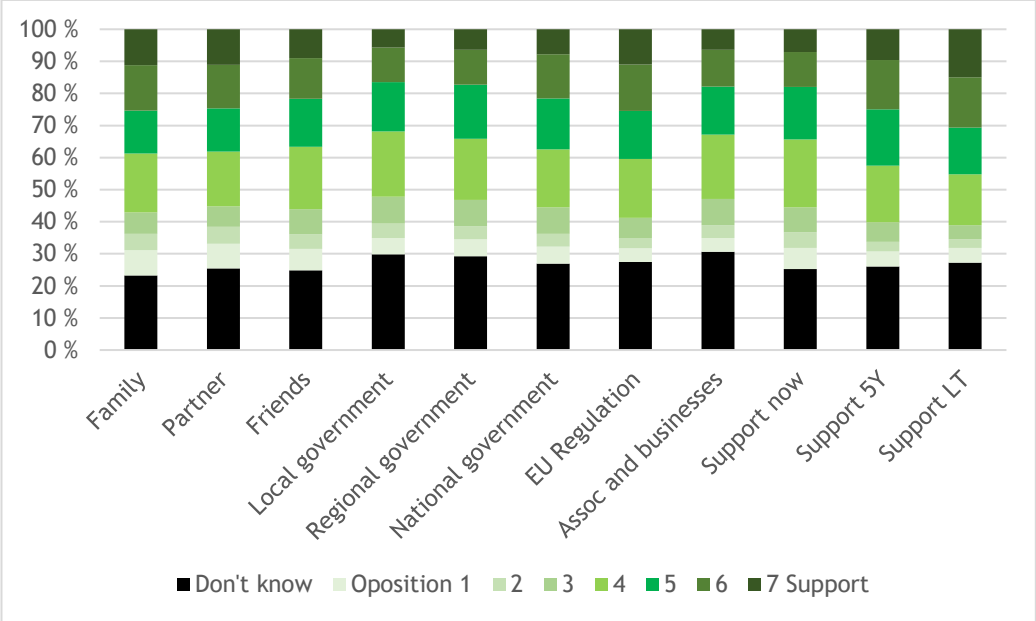


In contrast only a small percentage expect negative outcomes for their household in the different concepts included and for the environment. The reported outcomes for the future are only slightly better for 53% of the respondents. This later trend is in contrast with what is reported in the literature that is a significant increase in the acceptance of self-driving cars by society. This is specially the case when a significant number of respondents, about 20 average per question addressed, indicated not to be in a position to give an opinion or rate (simply answered: I don't know). It is worth to notice that the largest percentage about 25% of respondents indicated so for safety and privacy, issues that are paramount in the debate and research on CCAM, pointed out as major factors for acceptance or engagement in CCAM. Basic knowledge about the features and benefits of CCAM for a significant number of Europeans seems to be lacking.

3.3 Norms associated with engaging in GRETA

The social norm associated with CCAM engagement was assessed by asking about the level of support or opposition perceived in key stakeholders with some influence in the deployment of CCAM. The aim is to show how the different citizens perceive their important referents (i.e., peer citizens, regulators, business, social, political, communities, shareholders, staff, etc.). In general, it can be said that all actors are guided by, and within the limits of, the dominant social norms and values. The assessment of the social norm intends to gauge the extent to which any form of social or personal norm regarding the engagement in GRETA is present (and how strong it its) in the contexts where citizens live. Here it is hypothesized that those actors with a high perceived social pressure will be more inclined/prone to engage in GRETA. Figure 7 displays the captured trend in the survey sample.

Figure 7 CCAM social norm (N=3039)



Local, regional and national levels of government are reported to offer about the same level of support. This could be expected as so far national policy in European Member stages is dictating the form and level of support that new automotive technologies are receiving at the national level. Saying this, as it will be seen further below the local government actions in terms of regulations might be having the largest effect on the engagement of citizens in CCAM. Similarly, to government the social norm generated by referents close to the individual household (family, partner and friends) have very similar patterns on the perceived support. The reported general level of opposition to CCAM is relatively low about 12% average across diverse stakeholders, being slightly higher the opposition of association and businesses. This is aligned with was elicited during the interviews stage where some associations of manufacturer of motorcycles, logistics or digital industries producing mobility apps could play against CCAM (while others in favour). Similar to the trend reported about expected outcomes, for the role of

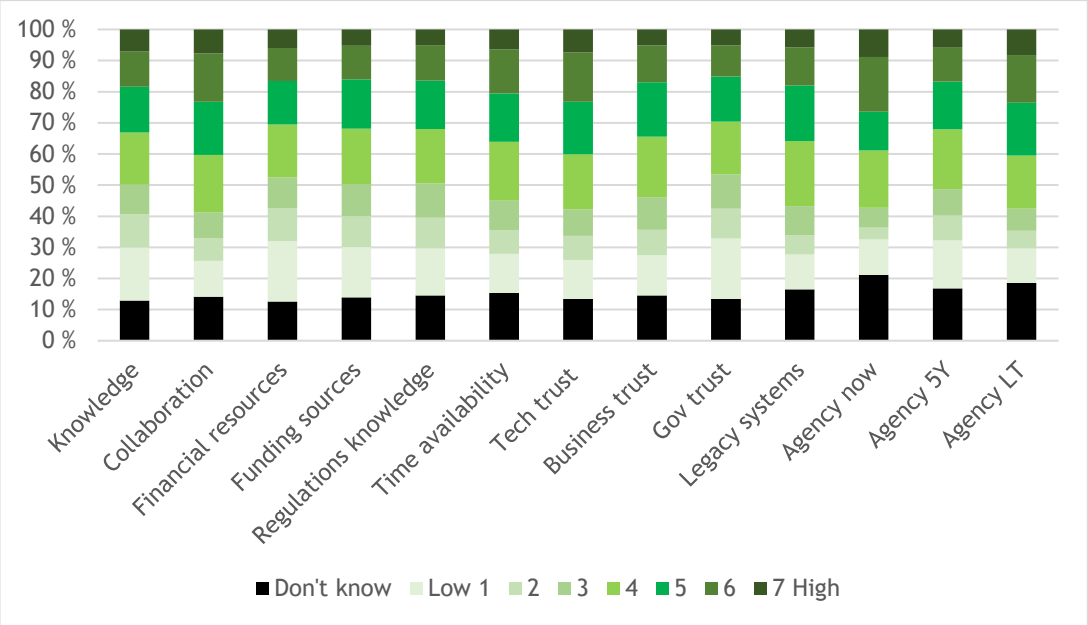
different stakeholders a significant number of respondents indicating having not sufficient knowledge to give an opinion (27% average across stakeholders indicated "I don't know").

The above level of awareness on technology or regulatory issues that are related to CCAM is rather abysmal. As seen in the policy landscape sketched in section 1.2 above there is a massive effort in technology and European norms to regulate the development and deployment of automated driving in Europe. Business and regulatory entities at the national and European level are deeply involved, contrasting with the marginal or not engagement of citizens. There is a great deal of effort to bring such knowledge and information on the implications of CCAM transition to citizens.

3.4 Agency associated with engaging in GRETA

Barring all other possible barriers agency to engage in any action supporting the transition to green energy is the ultimate determinant. That is agency determines action even when agency is enabled by others rather than the individual. The lower the agency of citizens (i.e., resources, skills, knowledge, networks, etc.) the lower the ability of citizens to engage in GRETA. Table 7 below shows the trend of reported agency across the survey sample. The agency was assessed in a scale varying from very low to very high. Table 7 indicates in average that about 51% reported to have low capacities to engage in CCAM whereby an average of 14% indicate not being able to assess their agency across all question items. About 18% indicated to have high capabilities to engage in CCAM. Citizens reported their capabilities to engage like knowledge and financial resources on CCAM as low (about 18% very low). Is interesting to highlight that trust was reported low by about 25% in the technology, business developing CCAM and government regulating. In particular the trust in government is low for about 41% of the respondents.

Table 7 Citizen's agency to engage in CCAM



Furthermore, the expected overall agency to engage within five years and in the long term is expected to change marginally. These trends indicate that there a significant effort to be made to enable the engagement of citizens in CCAM in the medium and long term. This initiative rest to a large extent in governments and business to best enable CCAM by providing knowledge, access to funding, increasing trust in the technology.

3.5 Relational model associated with engaging in CCAM

The previous sections describe the positive and negative outcomes, norms and agency aspects of that citizens associate with engaging in CCAM. Here we start bringing the relationship to other actors into the picture (with focus on policymakers and business). As summarized in GRETA Deliverable D1.1, according to Fiske's relational models theory (RMT), four structures operate when people interact (e.g., transferring things and ideas, bilateral exchange, contribution, distribution, etc.) and they set the terms defining the primary standards of social justice manifest in group decisions and social influence. In addition, RMT argues that all social relationships can be understood and organised by the combination of four models and that over time one archetypical relation can evolve, combining models or mutate from one model to another (Fiske, 1992). The aim of this section is to identify the dominant model that moderatea the relationships between the different actors and the preferred model of interaction that would foster the engagement in CCAM. This will start giving a picture of what is the model that is conducive to convergence to common green energy transition action goals in the case study.

The scale of relational model included two questions, one eliciting the dominant relational model between citizens and government and citizens with business. The second question elicits the preferred relational model that would support best the transition to CCAM, we called this "relational shift". The measurement scale varies from the market pricing (MP) to community sharing (CS) as theorised by the RMT. It is proposed that the scale varies in social preferences that move from individualistic (MP) to collectivist (CS). Following this logic the scale was gauged to vary from 1 (MP) to 4 (CS). This simple scale creates sufficient discriminatory power to assess preferences in relational models across respondents and across actors (citizens, policymakers and business). Figure 8 below depicts the trends on perceived dominant relational model and desired relational shift that would support best the transition to CCAM as reported across the survey sample by citizens.

Figure 8 Relational model shift (N=3039)

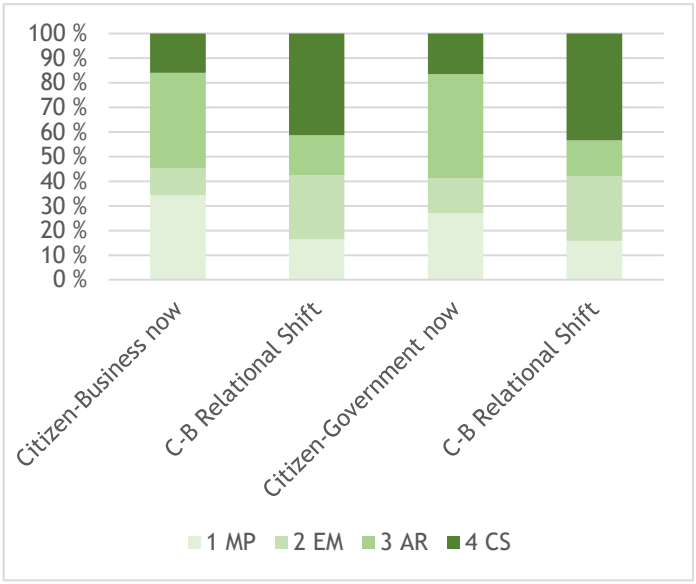


Figure 8 above clearly depicts a mismatch in citizen's between the dominant and preferred models of interaction with government and business. The relationship between business and citizens currently is dominated by a combination of market pricing (everything has a price) and authority ranking (business dictates the rules of the interaction), whereby equality matching and community sharing are less important. This contrast with the preferred relational model that would best support the CCAM transition, community sharing and equality matching. Both desired models of interaction have higher value of communal interaction. A very similar pattern of preferences by citizens are expressed for the relation reported with government. This marks the need for a significant change that questions the current form of social interaction and the rules that might guide the social change required. The test done is simple but indicates that more emphasis communal values would best underpin the engagement of citizens in CCAM.

3.6 Model validation: preliminary search for hidden patterns

The sections above describe the trends in sample but how well these trends actually relate an predict engagement in CCAM? This section deals with the validation of the model proposed in D1.1 and the corresponding testing of the set of hypotheses out lined in section 1.3 above. The testing and model validation consists of three test: reliability of measurement scales included in the model (H2), the hypothetical structure of the model (H3 and H4), and the content of the model (H1).

3.6.1 Reliability of scales

The reliability of the scales used in the model are indicated in Table E is tested via a Cronbach Alpha test. This test assesses the inter-correlation of a number of items measuring a specific construct or concept. The higher the inter-correlation index Alpha, the higher the reliability of the scale. This analysis indicates that all the items included in the respective scale contribute to the overall semantic load of the concept assessed. Table E below shows the Alpha test results for the scales included in the model; all scales are higher than the standard threshold of 0.60 intercorrelation index thus fulfilling the reliability test.

Table 8. Chronbach alpha test - items inter-correlation

Scale	Cronbach α	Items
Environmental risk	,907	14
Potential outcomes	,936	9
Social norm	,931	8
Agency to engage	,951	10
Relational model	,756	4
Emotion	,854	8

N=9414

The data included in the analyses consist of 9414 valid and complete questionnaires that addressed a number of case studies that used the same questionnaires with the same scales. The variation of the questionnaire was only in the leading question to each scale to generate the contextual meaning of the respective case study. Thus, the reliability test includes all cases and makes a stronger case for the reliability of the scales used in the survey. The analysis of the data, in spite of the number of observations, indicates a high internal coherence of the scales proposed in the behavioural model. **This test addresses and confirms H2 proposed in D1.1**.

- H2: All items included in each of the scales measuring ENG, OUT, SN, AG, RM and EM have a high internal cohesiveness enabling a reliable measurement and scaling of the concepts underlying the construct.

3.6.2 Structural validity

The model proposed is structured around six major clusters that aggregate a large variety of determinants of citizens engagement in CCAM. The test of the validity

consists in contrasting the theoretical structure of such clustering with the empirical one rendered by the aggregation and clustering of all variables around the six hypothesized components, thus testing H3 and H4 as proposed in D1.3.

- H3: The structure of the quantitative data matches the structure of the relations defined in H1: ENG= ENG(OUT, SN, AG, RM, EM).

- H4: A confirmatory factor analysis on the empirical data converges to a solution of six dimensions ([1 & 2] cognitive, [3] normative, [4] instrumental, [5] relational and [6] emotive) confirming the structure of the model used to collect data.

The clustering and weight of each component (i.e., perceived outcomes ([1]to the environment and [2] the individual), [3] social norm, and [4] agency and resources of citizens, [5] the dominant relational model between actors and the[6] emotion that are elicited by engaging in CCAM) were calculated via a test of principal components. This test also serves to assess the robustness of the model for a particular application (for an in-depth discussion, see Corral 2002, pp.198-220).[45] If the empirical structure (i.e., the dataset) fits the model proposed (i.e., most of the variance is explained with six components) the model can be considered valid. This clustering serves as well to assess what component of factor is likely to be the most important to explain engagement in CCAM (thus ranking the importance of the factors, that could act as barriers or enablers of engagement in energy citizenship).

Table 8 below shows the result of a confirmatory factor analysis set at six components. As already indicted by the reliability analysis, the intercorrelation between items (questions) in the survey questionnaire is high. The items cluster according to the major constructs indicated by the proposed theory in Deliverable D1.1.

[45] Montalvo C.C. (2002) *Environmental policy and technological innovation: Why do firms adopto or reject new technologies?* New Horizons on the Economic of Innovation. Cheltenham, Edward Elgar, 304 pp.

Table 9 Model component matrix

	Content	Component 1	2	3	4	5	6
Environmental outcomes [3]	Controllability	0,075	0,008	0,622	0,031	0,017	-0,030
	Treath	0,155	0,000	0,797	0,033	-0,076	-0,090
	Impact discounting in space - Local-Far	0,088	-0,028	0,737	0,049	-0,091	-0,037
	Consequences nonfatal - fatal	0,109	-0,014	0,812	0,022	-0,050	-0,084
	Distribution equity	0,024	0,000	0,665	0,047	0,041	0,015
	Catastrophe level	0,105	-0,004	0,836	0,021	-0,045	-0,095
	Effects to future generations	0,131	-0,054	0,811	0,040	-0,092	-0,070
	Voluntariness of exposure	0,021	-0,030	0,759	0,044	-0,025	-0,042
	Effects on the individual	0,068	-0,023	0,770	0,000	-0,041	-0,104
	Observability	-0,082	0,030	0,275	-0,027	0,112	0,055
	Knowledge of exposure	0,017	0,018	0,638	-0,010	-0,007	0,012
	Delay of effects	0,009	0,059	0,596	-0,021	-0,034	0,010
	Neweness of risk	-0,048	0,005	0,482	0,042	-0,005	0,058
	Certainty of effects:	0,089	-0,031	0,704	0,045	-0,075	-0,096
Outcomes to the individua & household [C1]	Safety	0,755	0,111	0,048	0,170	-0,008	0,018
	Emissions and environment	0,786	0,080	0,072	0,192	-0,035	0,051
	Complying with regulations	0,795	0,084	0,068	0,227	-0,035	0,060
	Our comfort and convenience	0,813	0,111	0,052	0,173	-0,002	0,039
	Our economy	0,777	0,162	0,063	0,152	-0,002	0,048
	Our autonomy	0,796	0,146	0,056	0,159	0,027	0,027
	Participation in our community	0,800	0,134	0,054	0,207	0,021	0,043
	Our health	0,812	0,113	0,056	0,185	-0,019	0,035
	Our internet privacy	0,690	0,127	0,027	0,191	0,038	0,041
Social norm [C4]	Family	0,485	0,209	0,092	0,496	0,080	-0,086
	Partner	0,471	0,199	0,089	0,504	0,068	-0,092
	Friends	0,437	0,181	0,083	0,597	0,092	-0,068
	CCAM_Local government	0,238	0,107	0,013	0,883	0,077	-0,005
	CCAM_National government	0,225	0,101	0,022	0,893	0,085	-0,005
	CCAM_National government	0,211	0,114	0,022	0,881	0,087	-0,003
	CCAM_European regulation	0,249	0,095	0,054	0,854	0,066	-0,019
	From associations and businesses	0,249	0,099	0,051	0,848	0,084	0,004
Agency to engage in CCAM [C2]	Knowledge	0,066	0,831	-0,040	0,025	0,088	0,009
	Capacity to collaborate with others	0,147	0,813	0,035	0,095	0,049	-0,005
	Financial resources	0,114	0,835	-0,053	0,084	0,129	0,011
	Knowledge on funding sources	0,102	0,881	-0,033	0,070	0,079	0,031
	Relevant laws and regulations	0,102	0,883	-0,038	0,080	0,090	0,022
	Availability of time	0,163	0,854	-0,005	0,079	0,053	0,013
	Trust on technical solutions	0,214	0,857	0,027	0,053	0,025	-0,038
	Trust on business	0,189	0,856	0,006	0,090	0,067	-0,038
	Trust on government	0,147	0,792	0,009	0,134	0,120	-0,041
	Legacy system lock in	0,136	0,774	0,041	0,152	0,057	-0,012
Dominant relational model [C6]	Current relational model with business	0,086	-0,047	0,009	0,021	0,072	0,635
	Ideal relational model with business	0,000	0,050	-0,122	-0,044	0,102	0,730
	Current relational model with government	0,058	-0,017	0,003	-0,037	0,098	0,666
	Ideal relational model with Government	-0,006	0,070	-0,109	-0,062	0,118	0,711
Engagement elicited emotion [C5]	...good	0,553	0,282	0,119	-0,047	0,393	-0,371
	...proud	0,507	0,307	0,103	-0,050	0,466	-0,376
	...worthwhile	0,545	0,268	0,125	-0,054	0,425	-0,380
	...satisfied	0,527	0,296	0,122	-0,050	0,435	-0,390
	...bad	-0,043	0,072	-0,115	0,166	0,803	0,196
	...guilty	0,068	0,164	-0,081	0,098	0,873	0,101
	...pointless	-0,042	0,117	-0,113	0,144	0,820	0,176
	...remorseful	0,062	0,139	-0,077	0,107	0,869	0,113

N=3039 observations. Extraction Method: Principal Component Analysis.

a. Rotation converged in 6 iterations.

Items of perceived risk and potential environmental outcomes cluster in component C3; Items of perceived outcomes for the individual household cluster in component C1; the perceived social norm and support to CCAM cluster in component C4; Items corresponding to the assessment of citizens agency to engage cluster in component C2; Items pertaining to the perception of the dominant relational model of citizens with policymakers and businesses cluster in component C6 and; the emotion elicited by engaging (or not) in CCAM cluster in component C5. **The clustering confirms hypotheses H3 and H4, the empirical structure of the data mirrors the structure of all major theoretical constructs in the behavioural model applied to the CCAM case study**.

Furthermore Table 9 below indicates the amount of variance explained by each component in the model totals 65,5% of the variance in the sample. The analysis was based on responses to the CCAM case only with 3039 usable questionnaires.[46] The cognitive component on outcomes explains 28% of the variance in the sample. While citizens agency to engage explains 14.6% of the variance. The high variance explained is primarily due to the low number of cases in the sample. The variation and, thus, discriminatory power of the sample is high. In general, the results of this reduction dimension analysis indicates high coherence concerning the structural validity of the model.

Table 10 Factor Analysis: Variance explained by model of six components

	Initial Eigenvalues			Loadings			Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	13,176	24,860	24,860	13,176	24,860	24,860	7,886	14,880	14,880
2	7,423	14,006	38,867	7,423	14,006	38,867	7,749	14,621	29,500
3	4,970	9,377	48,243	4,970	9,377	48,243	6,950	13,112	42,613
4	3,225	6,085	54,329	3,225	6,085	54,329	5,156	9,728	52,341
5	3,018	5,694	60,023	3,018	5,694	60,023	3,789	7,149	59,490
6	2,375	4,481	64,504	2,375	4,481	64,504	2,657	5,014	64,504

Extraction Method: Principal Component Analysis.

A first conclusion that can be drawn from the analysis above is that in any policy initiative oriented for promote the engagement of citizens in CCAM is to provide clear information clarifying the nature of CCAM the benefits and costs this implies for the users and the environment as well as the net gains in energy efficiency in the vehicle itself and the mobility system as a whole. This insight is backed up by the high proportion of the variance explained by the cognitive components of the behavioural model and is likely to have a significant effect in the future engagement of citizens in CCAM. This must be compound with fostering the agency to engage in CCAM.

3.6.3 Content validity

The content validity test consists of assessing to what extent the variables included in the model can predict the dependent variable. This concerns hypothesis H1 that brings the coherence of the theory to the forefront.

H1: The citizens engagement (ENG) in GRETA can be explained in terms of the citizens' outcomes arising from the engagement in GRETA (OUT), the dominant social norm to engage in GRETA (SN), the level of agency exerted on GRETA (AG) as perceived by citizens, relational model mediating interactions with other actors

[46] Equaly good fit results in the analysis of the whole survey sample with 9404 observations. See Annex 2.

(RM), and the emotional state of citizens elicited by engagement in the energy transition (EM).

This was expressed as:

$$ENG=ENG(OUT, SN, AG, RM, EM)$$

In other to test this hypothesis a linear regression was conducted in the data running three regressions to assess whether the data on engagement could be fitted for engagement in CCAM currently (CCAM_ENG_now), within five years (CCAM_ENG_5Y) and in the long term (CCAM_ENG_LT). The explanatory variables were the scales in each of the six constructs as outlined in the previous sections, these being:

- Environmental risk perception scale
- Expected outcomes scale
- Social norm scale
- Citizens engagement agency scale
- Dominant RM model scale
- Emotion engagement scale

The scales listed above capture all the conative loading of all the items included in the questionnaire and offer a large discriminatory power amongst the participants in the survey. The scales vary from 14 to four items where all scales resulted to be highly reliable capturing the conative loading the are intended to measure. Table 10 below presents the synthetic results of the regressions for the three engagement temporal scales assessed. The results confirm H1 and the theoretical proposition that the engagement of CCAM by citizens can be explained in the terms outlined as H1.

It can be expected that the determinants of engagement vary in importance across time and across different segments of the sample stratification. Is likely as mentioned early that young citizens and those with higher incomes (generally older) will hold different motivation and degrees of engagement.[47] Here the results presented work for the central trend of the sample. Taking into account this caveat the model tested results satisfactory to explain the citizens engagement in the adoption and use of CCAM. The model for CCAM engagement has the best fit when considering engagement in the middle and long term.

Table 11 H1: cross time test_best model fit

Temporal scope of Engagement	R	R2	Adj. R2	SEE
Engagement currently	0,33	0,11	0,11	0,76
Engagement within 5 years	0.538	0.289	0.287	1,7
Engagement in the long term	0,503	0,253	0,251	1,836

[47] Such analysis is out of the scope of this report.

Table 12 Regression of Engagement vs scales

ENG vs scales now

	R	R2	Adj. R2	SEE	
	0,33	0,11	0,11	0,76	
	Sum of Squares	df	Mean Square	F	Sig.
Regression	170,95	3,00	56,98	97,39	<,001
Residual	1387,95	2372,00	0,59		
Total	1558,91	2375,00			
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1,29	0,07		18,03	0,00
Citizens engagement agency scale	0,02	0,00	0,26	10,83	0,00
Social norm	0,01	0,00	0,08	3,24	0,00
Dominant RM model scale	0,02	0,00	0,06	3,18	0,00

a. Dependent Variable: CCAM Engagement currently

ENG_5Y vs scales

	R	R2	Adj. R2	SEE	
	.538	.289	.287	1,7	
	Sum of Squares	df	Mean Square	F	Sig.
Regression	2857,47	6,00	476,24	160,61	<,001
Residual	7024,47	2369,00	2,97		
Total	9881,94	2375,00			
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-0,66	0,24		-2,80	0,005
Citizens engagement agency scale	0,04	0,00	0,27	11,59	0,000
Expected outcomes scale	0,02	0,00	0,15	6,72	0,000
Emotion engagement scale	0,02	0,00	0,11	6,17	0,000
Dominant RM model scale	0,06	0,01	0,09	5,21	0,000
Social norm scale	0,02	0,00	0,11	4,98	0,000
Environmental risk perception scale	0,01	0,00	0,07	3,96	0,000

a. Dependent Variable: CCAM Engagement within 5 years

ENG_LT vs scales

	R	R2	Adj. R2	SEE	
	0,503	0,253	0,251	1,836	
	Sum of Squares	df	Mean Square	F	Sig.
Regression	2698,616	6	449,769	133,480	<,001[g]
Residual	7982,474	2369	3,370		
Total	10681,090	2375			
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	0,09	0,25		0,34	0,731
Expected outcomes scale	0,03	0,00	0,21	9,45	0,000
Citizens engagement agency scale	0,03	0,00	0,17	7,32	0,000
Dominant RM model scale	0,08	0,01	0,12	6,40	0,000
Environmental risk perception scale	0,02	0,00	0,12	6,42	0,000
Social norm scale	0,02	0,00	0,10	4,09	0,000
Emotion engagement scale	0,01	0,00	0,07	3,82	0,000

a. Dependent Variable: CCAM Engagement long term

Table 12 displays the detailed test for each of the three regression where it can be seen which explanatory variables are the most important in moderating engagement in CCAM. The empirical fitness of the model for future engagement can be in part explained by the very level of its early stage and that most people engaged in the survey reported to have little information currently over CCAM or having information but currently not engaged in CCAM. So most positive reporting refers to the medium

term or long term expectations. This fact play out well for policy analysis is the CCAM field as in European policy efforts and in particular the CCAM partnership expect to increase the effort of engaging citizen in the next years.

What is worth noticing is that almost all variables included in the model hold a positive relationship with the expected engagement of citizens within the next five years and in the long term. This shows the coherence of the method chosen to measure. All scales vary from a low to high score in their respective semantic meaning. Low environmental risk perception indicates a low relevance for environmental outcomes and likely engagement. Low scores in outcomes for the individual household might is likely to imply low engagement. Low agency might be associated with low engagement. A high score in the scale of relational model variating from an individualistic to a communal relational model indicates a likely higher engagement in CCAM. These assumptions are validated by the coefficients of the regression for all temporal variations of Engagement in CCAM (now, 5 years and long term).

Looking at the three regressions coefficients it worth noticing that the most important variables in explaining engagement across time are: the relational model with other actors and the level of agency (knowledge and resources available) to engage. First, this points out to the importance to look more in detail on the nature and role of relationships and interactions amongst stakeholders. The higher the communal orientation of the relation the higher the expected impact in the engagement of citizens in CCAM. This is a major finding as most relationships in the social life interacting with business are rule by market pricing relational model. Similarly, the relationship with government are ruled by an authority ranking relational model. As indicated in the descriptive trends in the previous section, the mismatch between the current dominant relational model and the most desirable one is significant.

A major tenant of the RM Theory is that the congruence in alignment or combination in the algebra of the relational model explains social outcomes. Relations mediated by dyadic expectations in a combination pool of Community sharing (CS)-Authority ranking (AR)-Equality matching (EM) are likely to hold and others mediated in a pool AR-EM-Market pricing (MP) are very likely to hold as well. Relations mediated by models expectations on CS-MP, CP-EM, MP-AR for example are unlikely to work leading to a collapse of the social relationship. The later algebra of relational models lead to two hypotheses.

H5: Congruence and alignment of relational models has a significant positive effect on the individual and collective engagement in GRETA.

H6: Dissonance between relational models has a significant negative effect on the individual and collective engagement in GRETA.

3.6.4 Correlation between major factors influencing CCAM engagement

In the previous section the most important factors that explain engagement in CCAM were identified. In this section the relationships between such factors is explored. The aim of the bi-correlation analysis is to uncover patterns, for example whether a significant relationship exists between the major empirical constructs that integrate the proposed behavioural model. Table 13 below shows the results of a correlation analysis conducted in the CCAM case study data set.[48]

Table 13 Relations between major factors influencing citizen engagement in CCAM

SCALES	CCAM ENG Now	CCAM_ENG5Y	CCAM_ENG LT	Environment risk scale	Expected outcomes scale	Social norm scale	Citizens agency scale	Dominant RM scale
CCAM Engagement currently	--							
	3036							
CCAM_ENG Within the next five years	,361**	--						
	0,000							
	3036	3036						
CCAM_ENG in the longer term	,313**	,734**	--					
	0,000	0,000						
	3036	3036	3036					
Environmental risk perception scale	0,033	,122**	,188**	--				
	0,069	0,000	0,000					
	3036	3036	3036	3036				
Engagement expected outcomes scale	,218**	,404**	,409**	,177**	--			
	0,000	0,000	0,000	0,000				
	2685	2685	2685	2685	2685			
Social norm for energy citizen engagement scale	,249**	,416**	,372**	,078**	,525**	--		
	0,000	0,000	0,000	0,000	0,000			
	2490	2490	2490	2490	2425	2490		
Citizens engagement agency scale	,341**	,485**	,414**	0,023	,522**	,596**	--	
	0,000	0,000	0,000	0,229	0,000	0,000		
	2725	2725	2725	2725	2566	2427	2725	
Dominant relational relational model scale	,127**	,208**	,238**	,141**	,205**	,172**	,160**	--
	0,000	0,000	0,000	0,000	0,000	0,000	0,000	
	3036	3036	3036	3036	2685	2490	2725	3036
Emotion engagement scale	0,012	,077**	0,027	0,002	,133**	,245**	,171**	,039*
	0,525	0,000	0,144	0,895	0,000	0,000	0,000	0,031
	3036	3036	3036	3036	2685	2490	2725	3036
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

Key highlights of the correlation analysis concern the strong association of some factors with engagement. The strongest association of engagement is with agency of citizens to engage in CCAM currently, within five years and the long term. This is followed by the association with norms across all temporal items and by the expected outcomes from engaging in CCAM currently and the long term. The state of the

[48] The correlation analyis was conducted in the whole data set and also in a set whereby the scores in items rated at the point 8 (I don't know) of the scale were removed from the analysis. These scores were substantially large to skew the data set thus losing properties of a normal distribution. The results of the test are very similar. The correlations identified in direction and intensity hold in both analyses. The only difference is a slightly lower association between construct but such differences seem to affect proportionaly all factors. This renders the results of both data sets analyses rather similar. Here we display the analysis conducted in the whole data set.

environment and the perceived effect that CCAM might have in improving the sustainability of road transport vehicles is associated with engagement but is less strong than other constricts like policy support (social norms), agency or the relational model. There is a significant positive association of engagement in CCAM with the relational model. The emotion elicited by the perspective of engagement within five years is significant by much lower in strength compared with other factors. This last finding is aligned with the notion that emotion is a stronger determinant in the short term, which in this case is not associated with the current levels of engagement in CCAM. These set of significant correlations indicate that efforts must be placed enabling citizens' agency and in providing information to foster knowledge on CCAM technology and the regulatory frameworks supporting it. Furthermore, the correlation between engagement in CCAM and the level of mismatch between market pricing and community sharing indicates a significant negative effect in citizens engagement. Policy supporting CCAM must place emphasis on communal values rather than market based policies.

4 Discussion and reflection

4.1 Discussion and reflections of case study results in light of policy recommendations

The advent of connected and cooperative automated mobility promises significant gains in the reduction of road traffic deaths (ZERO deaths) and CO2 emissions (ZERO CO2 goal). Both goals are set to significantly increase the energy efficiency of the mobility system as it brings transformational changes in road and communication infrastructures and usage of vehicles. Over that last five years efforts and investments to develop reliable CCAM technologies and the accompanying regulatory have been very large. Business and governments have been very active while the participation and awareness of citizens of such developments have been marginal or absent. This is demonstrated by the level of engagement in CCAM by citizens and shown in the section describing trends of engagement across the participants in the European survey whereby only mere 10% of the survey participants indicated to have knowledge and being engaged in CCAM. This contrasted with a large majority not knowing about it (about 80%).

4.1.1 Major drivers and policy priorities

Major constrains for the engagement of citizens included the lack of knowledge on the benefits and costs of CCAM for the individual household and the environment. The lack knowledge on the technology is likely to underpin the lack of trust in the technology itself and in the business promoting it. This also is likely to be associated with the lack of trust in government. There is also a large lack of awareness and knowledge on the upcoming regulatory framework that addresses safety of the vehicle but also all data flows and privacy issues associated with the provision of services that are data driven, data that originates from the behaviour of the passenger while using a self-driving car. There is little knowledge about the implications of the use of personal data of citizens.

Concerns about safety and accidents avoidance, cost of ownership (maintenance and battery replacement), model of use available (full ownership or pay as used), environmental benefits, recharging features and associated driving range with recharging infrastructures. All these seemed to be issues associated with engaging in CCAM.

For policy priorities, policymakers could be guided by the indication of what is strongly associated with CCAM engagement. From the regression and correlation analyses it can be said that there is a positive influence between major all major constructs included in the theoretical model guiding the empirical enquire. Environmental effects of CCAM, the likely outcomes of engaging, the perceived norm

and support, the agency available and the relational model mediating the relation with policymakers and business, all play a role.

Priority must be given to agency, norms and perceived outcomes in this order of intervention. There is a strong relationship between these three meta-drivers, improving agency improves the other two drivers. Knowledge on the technology and access to funds are key drivers. Barring all drivers, that is, once those are addressed by policy, an effort must be placed in redefining the relational model between the three actors to place emphasis in communal values supporting the transition to CCAM and in turn support the green energy transition. Is critical to put clear the supporting role of single transitions like CCAM and how these contribute to the larger picture of green energy transition and in general sustainability.

4.1.2 Energy communities

Relative other cases there are no communities of citizens engaged in CCAM as the use of cars has been largely an "individual household" affair. CCAM offers a large potential for a shift to communal sharing of mobility means as the cars become part of the internet of things and facilitate rides-sharing or auto-sharing in the long term deployment of CCAM. The notion of energy community might be related the dominant relational model identified during the survey. Currently the dominant relational model is guided by "market pricing and authority ranking" where the survey respondents indicated to have a preference for a shift to "community sharing and equality matching" mode of relation with business and policymakers. These seem to have an implicit higher level of citizen engagement at it calls for higher level of democratic involvement. The later calls for the renewal of the current "social contract" between the three actors considered in the study. This aspect as a strong link to the notion of developing new "community contracts" supporting the green energy transition.

4.1.3 Social justice

The notion of social justice is strongly related to the level of engagement. A correlation analysis between key variables indicating inclusion (income, level of education and age). The empirical stage of the enquire indicates that younger people tend to be less likely to be engaged in CCAM currently, within the next five years and in the long run as reported in the survey. Furthermore, the level of education and income are associated with the engagement in CCAM. The correlation analysis indicates that higher the level of income and education the more likely for citizens to engage in CCAM. This implies that the design of policy supporting CCAM engagement must consider that younger citizens, low educated and low income are to strongly be considered in the policy design. All drivers indicated above apply here but is likely that inclusion policy and intervention in aspects related to agency are to play a key role in promoting energy citizenship in young, low educated and with low income.

4.1.4 Role of policy

As described in section 1.2 there is currently a massive policy effort to put in place a regulatory framework that promotes and provide regulatory certainty in many aspects (technology, markets, finance, digital assets, cybersecurity and privacy, etc.) related to supporting the transition to CCAM. The large set of regulations that are in process of implementation across the European landscape indicates that this is to be a major paradigm shift in transport and mobility. Despite the little knowledge reported by citizens about the regulatory framework, the relationship of regulations and policy support are strongly associated with their expected engagement in the medium and long term. It can be expected that communication campaigns could have a significant effect on citizens engagement in CCAM. In particular, is importance to notice that policy support at the local and regional level are relatively more significant that national or European policy support. This can be expected, policies and general regulatory guidelines for transport and mobility are enacted at the European level but are implemented at the national level, in particular by the regions and municipalities (often at the city level). As conclusion, the level of intervention to promote energy citizenship must be done at the local and regional level.

4.1.5 Key message to policymakers and business

The engagement in CCAM will be strongly moderated by age, education and income levels. Second factor concerns the enablers of engagement in the following order: like knowledge (technology, benefits and cost, new rules and regulations) and the regulatory framework. Barring the above, the cooperative and digital nature of the new technology seem to demand also a shift towards a culture and social contract based in values of “community sharing and equality matching” in contrast with the current “market pricing and authority ranking”. This calls for a more decisive engagement of citizens in the development and deployment of CCAM. Taking behavioural drivers into consideration into the design of policies promoting change, promoting the energy transitions is relatively new. This brings a challenge not only of designing the appropriate format of a new social contract. Also it brings the challenge of delivering a policy mix that tackles information provision, enabling power to engage and shaping the modality of interaction between actors. If we believe the empirical evidence provided in this case study, this is a new territory that must be explored and developed in order to support the energy transition.

5 Conclusion

The framework proposed to enquire about the emergence of energy citizenship lead us to select specific cases that would demonstrate beyond a sociological and policy concept. This is, what means in practice for citizens to engage in energy citizenship, and what would motivate such engagement. The theoretical framework lead us to the selection of a number of cases that would demonstrate in practice, what citizens could do to contribute to the energy transitions. Six cases of specific engagement were considered in GRETA one of which is the engagement in new forms of mobility that support higher energy efficiency in the transport system. The framework enabled an enquire that would be applied to all six cases to enable comparisons. This report provides input for such comparison in a later stage in the GRETA project. The overall experience in the empirical enquire has three major conclusions that merit mention.

5.1.1 The trends identified in CCAM engagement and drivers

The descriptive analysis of the trends in engagement and drivers show that currently there is little engagement in CCAM, this reflects the level of development and deployment of the Level 3 of automation. It cannot be otherwise that the data reflects that. It worth to highlight that the level of knowledge about the CCAM transition and capacity to engage is lacking in the citizenry, engagement must be promoted by business and government. Similarly

5.1.2 The validity of the framework

The tests conducted in the hypothesis posed at the outset of this enquire produced confirmatory results. The reliability of the scales was found not only satisfactory but high, validating the reliability of measurements of the constructs of interest for all scales used. The structure of the model was confirmed by a multidimensional scale analysis, testing the validity of the six constructs that integrate the framework. The analysis indicated that up to 63% of the variance was explained by the six components. This also indicated a clear cut of six dimensions in the empirical data, indicating a correspondence between the theoretical framework and empirical structure of the survey data. The analytical framework enabled the reduction and efficient analysis of a large array of data that uncover hidden patterns that drive engagement in energy citizenship. Such hidden patterns are not recognizable in the descriptive statistics nor in the qualitative stage of the enquire.

5.1.3 General overview of policy and engagement of citizens

The energy transition and climate resilience and the transition to autonomous mobility are two trends that will influence each other in the long run. The mutual influence of different drivers creates positive synergies. Saying this, the regulatory framework for the development and deployment of the most advanced levels of automation is extensive and complex. The advent of this relatively new regulatory framework will take time to be implemented across member states. It will require an effort not only of

national authorities but also business to adapt and operate in this new regulatory framework. Business and national authorities are still at the early dawn of awareness of the implications of the advent of the digital mobility and its regulatory system. At the side of the end user of these technologies many of these regulations are not visible as they are embedded in the systems that provide the service of mobility, that is the vehicle and the enabling infrastructure. Most citizens operate their vehicles not being aware of the regulatory system supporting the operation of the vehicle park beyond aspects and issues related to private insurance, road rules and licencing. The advent of new vehicles with CCAM capabilities might require more awareness of such regulatory matters in other to better adopt and use these new systems.

5.1.4 Key message to policymakers and business (repeated)

The engagement in CCAM will be strongly moderated by age, education and income levels. Second factor concerns the enablers of engagement in the following order: like knowledge (technology, benefits and cost, new rules and regulations) and the regulatory framework. Barring the above, the cooperative and digital nature of the new technology seem to demand also a shift towards a culture and social contract based in values of “community sharing and equality matching” in contrast with the current “market pricing and authority ranking”. This calls for a more decisive engagement of citizens in the development and deployment of CCAM. Taking behavioural drivers into consideration into the design of policies promoting change, promoting the energy transitions is relatively new. This brings a challenge not only of designing the appropriate format of a new social contract. Also it brings the challenge of delivering a policy mix that tackles information provision, enabling power to engage and shaping the modality of interaction between actors. If we believe the empirical evidence provided in this case study, this is a new territory that must be explored and developed in order to support the energy transition.

Annex 1. Questionnaire CCAM citizen engagement

Part A – General Information

Respondent type : ☐ Citizen ☐ Business ☐ Government

CASE: Autonomous and connected vehicles

Part B – Engagement level and planned actions

To what extent has your household has been engaged in activities to use (buying, renting or leasing) an electric vehicle with an autonomous and connected capacity (eg., VW, Toyota, Tesla, Wymo, etc).

We are unaware of autonomous and connected cars.	☐
We know about it but not using	☐
We are using	☐
We are promoting it	☐
We are actively championing it	☐

To what extent does your household has existing plans to use (buying, renting or leasing) an electric vehicle with an autonomous and connected car?

Part C – Potential outcomes

Outcomes for the environment and society

The environmental problems generated by the usage of use of current gasoline and diesel are likely to be:

controllable	☐	☐	☐	☐	☐	☐	☐	uncontrollable
not threatening	☐	☐	☐	☐	☐	☐	☐	threatening
of very local impact	☐	☐	☐	☐	☐	☐	☐	of global impact
with no fatal consequences	☐	☐	☐	☐	☐	☐	☐	with fatal consequences
equally distributed	☐	☐	☐	☐	☐	☐	☐	affecting people very unequally
non-catastrophic	☐	☐	☐	☐	☐	☐	☐	catastrophic
not affecting future generations	☐	☐	☐	☐	☐	☐	☐	affecting future generations very strongly
voluntary for those exposed	☐	☐	☐	☐	☐	☐	☐	involuntary for those exposed
not affecting me	☐	☐	☐	☐	☐	☐	☐	affecting me
observable	☐	☐	☐	☐	☐	☐	☐	not observable
unknown to those exposed	☐	☐	☐	☐	☐	☐	☐	known to those exposed
arising with long delay	☐	☐	☐	☐	☐	☐	☐	arising immediately
new risk	☐	☐	☐	☐	☐	☐	☐	old risk
pure speculation	☐	☐	☐	☐	☐	☐	☐	scientifically confirmed

EV1.The environmental effects generated in the use of diesel and gasoline cars are likely to be: (low –high)

At the moment
Within the next five years
In the longer term

EV2. As consequence from an environmental perspective the usage (by buying, renting or leasing) an automated and connected car for our household is: likely-unlikely

At the moment
Within the next five years
In the longer term

Outcomes for the individual

My involvement in the usage (by buying, renting or leasing) an automated and connected car for my household is likely to result in the following effects:

	Factors	highly negative						Highly positive	I do not know
C1	Safety	☐	☐	☐	☐	☐	☐	☐	☐
C2	Emissions and environment	☐	☐	☐	☐	☐	☐	☐	☐
C3	Complying with regulations	☐	☐	☐	☐	☐	☐	☐	☐
C4	Our comfort and convenience	☐	☐	☐	☐	☐	☐	☐	☐
C5	Our economy	☐	☐	☐	☐	☐	☐	☐	☐
C6	Our autonomy	☐	☐	☐	☐	☐	☐	☐	☐
C7	Participation in our community	☐	☐	☐	☐	☐	☐	☐	☐
C8	Our health	☐	☐	☐	☐	☐	☐	☐	☐
C9	Our internet privacy	☐	☐	☐	☐	☐	☐	☐	☐
	Other (if applicable)								
C10	Please specify	☐	☐	☐	☐	☐	☐	☐	☐
C11	**Overall effect** GRETA initiative								
	Now?	☐	☐	☐	☐	☐	☐	☐	☐
	In five years?	☐	☐	☐	☐	☐	☐	☐	☐
	In the long term?	☐	☐	☐	☐	☐	☐	☐	☐

Part D – Norms (stakeholders)

How is the **support** given to the usage (by buying, renting or leasing) of an automated and connected car by the following stakeholders or parties?

		strong opposition						strong support	I do not know
D1	Family,	☐	☐	☐	☐	☐	☐	☐	☐
D2	Partner	☐	☐	☐	☐	☐	☐	☐	☐
D3	Friends	☐	☐	☐	☐	☐	☐	☐	☐
D4	Local government	☐	☐	☐	☐	☐	☐	☐	☐
D5	Regional government	☐	☐	☐	☐	☐	☐	☐	☐
D6	National government	☐	☐	☐	☐	☐	☐	☐	☐
D7	European regulation	☐	☐	☐	☐	☐	☐	☐	☐
D8	From associations and businesses	☐	☐	☐	☐	☐	☐	☐	☐
D9	Other stakeholder (if applicable)								
	Please specify	☐	☐	☐	☐	☐	☐	☐	☐
D10	**Overall** support from stakeholders?								
	Now?	☐	☐	☐	☐	☐	☐	☐	☐
	In five years?	☐	☐	☐	☐	☐	☐	☐	☐
	In the long term?	☐	☐	☐	☐	☐	☐	☐	☐

Part E – Agency to perform

How would you assess regarding knowledge and resources to use (by buying, renting or leasing) an automated and connected car?

		Very low						Very high	I do not know
E1	Knowledge (technical, infrastructure, equipment, etc.)	☐	☐	☐	☐	☐	☐	☐	☐
E2	Capacity to collaborate with others	☐	☐	☐	☐	☐	☐	☐	☐
E3	Financial resources	☐	☐	☐	☐	☐	☐	☐	☐
E4	Knowledge on funding sources	☐	☐	☐	☐	☐	☐	☐	☐
E5	Relevant laws and regulations	☐	☐	☐	☐	☐	☐	☐	☐
E6	Availability of time	☐	☐	☐	☐	☐	☐	☐	☐
E7	Trust on technical solutions	☐	☐	☐	☐	☐	☐	☐	☐
E8	Trust on business	☐	☐	☐	☐	☐	☐	☐	☐
E9	Trust on government	☐	☐	☐	☐	☐	☐	☐	☐
E10	Pre-existing **old energy appliances** within the household/building	☐	☐	☐	☐	☐	☐	☐	☐
E11	Other resources or knowledge Please specify	☐	☐	☐	☐	☐	☐	☐	☐
E12	**Your Overall** capacity to adopt/participate in the GRETA initiative								
	Now?	☐	☐	☐	☐	☐	☐	☐	☐
	In five years?	☐	☐	☐	☐	☐	☐	☐	☐
	In long term?	☐	☐	☐	☐	☐	☐	☐	☐

Part F - Relational models

My relation with business providing solutions for the usage (by buying, renting or leasing) an automated and connected car **is likely dominantly characterised by**:

- Everything is done by the common societal good ☐
- Business dominates and dictates the terms of the service ☐
- I pay back as I receive ☐
- Everything has a price ☐

Ideally this relation should be:

- Everything is done by the common societal good ☐
- Business dominates and dictates the terms of the service ☐
- All contributions and what we receive should be a tit for tat, I give as I receive ☐
- Everything should have a price ☐

My relation with government concerning the usage (by buying, renting or leasing) an automated and connected car **solutions is likely dominantly characterised by:**

- Everything is done by the common societal good ☐
- Government dictates the form and terms of our relation ☐
- I pay back as I receive ☐
- Every service has a price ☐

Ideally this relation should be:

- Everything should done by the common societal good ☐
- Government dictates the form and terms of our relation ☐
- All contributions and what we receive should be a tit for tat, I give as I receive ☐
- Everything should have a price ☐

Part G - Emotion

The idea of using (by buying, renting or leasing) an automated and connected car for **my household** makes me feel:

	Strongly disagree						Strongly agree	I do not know
... good	☐	☐	☐	☐	☐	☐	☐	☐
... proud	☐	☐	☐	☐	☐	☐	☐	☐
...worthwhile	☐	☐	☐	☐	☐	☐	☐	☐
...satisfied	☐	☐	☐	☐	☐	☐	☐	☐
... bad	☐	☐	☐	☐	☐	☐	☐	☐
...guilty	☐	☐	☐	☐	☐	☐	☐	☐
...pointless	☐	☐	☐	☐	☐	☐	☐	☐
...remorseful	☐	☐	☐	☐	☐	☐	☐	☐

Annex 2. Review factors influencing CCAM engagement

	Acceptance/engagement in CCAM	Studies
Perception of AVs	*Experience with and knowledge about AVs*: Awareness of AV technologies, interacting with AVs, satisfaction with in-vehicle technology, familiarity / experience with road automation (e.g., Advanced Driver Assistance Systems (ADAS), SAE Level 2-4), type of information about AVs	49
	Performance expectancy: Equivalent to perceived usefulness	31
	Effort expectancy: Equivalent to perceived ease of use	19
	Safety: Perceived safety, reliability, security, equipment and system failure, cyber security/fear of terrorism/hacking, system performance in poor/various weather and terrain or unexpected conditions (e.g., automated vehicles getting confused by unexpected situations, automated vehicles not driving as well as human drivers)	73
	Service and vehicles characteristics: Availability, flexibility, travel speed, travel costs, convenience, integration with other modes, comfort, charging time, interoperability, size, quality and design of exterior and interior, brightness, aesthetics, brand, vehicle behaviour and capabilities (e.g., dynamic object and event detection, overtaking and braking behaviour, longitudinal and lateral control)	45
Symbolic-affective system evaluation	*Hedonic motivation*: Equivalent to pleasure, enjoyment, fun	13
	Social influence: Equivalent to subjective norm, prestige, image	18
Moral-normative system evaluation	*Perceived benefits*: Higher productivity due to engagement in non-driving related activities, benefits for the environment (e.g., reduction of fuel consumption, emissions and traffic congestion, lower vehicle ownership), increased mobility independence and freedom for the elderly, disabled and others, no need for driver license/ to spend time and cost on learning how to drive, easier, quicker and less expensive parking, lower repair costs (in case of less accidents),increased jobs, lower insurance premiums	55
	Perceived risks: Legal liability of drivers or owners, date privacy (location and destination tracking), loss of driving skills and pleasure, interacting with manually controlled cars, pedestrians and cyclists, lack of assistance for disabled riders/passengers, affordability, traffic delays, ethical/social consequences (job losses, social isolation, loss of human element)	50
Socio-demographics	Age	65
	Gender	58
	Household structure: Number of people in household, number/presence of children, workers, dependent people in household, age of child, marital status	17
	Education	34
	Income	29
	Employment: Employment status, jobs per household, social class, number of workers in household, flexible work schedule (e;g., offered flex-time, permit to compress work schedule)	16
	Residential situation: Place of residence, house type, home location, region, ethnicity, nationality, immigration status	28
Travel behaviour	*Access to mobility*: possessing valid driver license or public transport pass, car/Diesel vehicle/electric vehicle ownership, number of vehicles per household, age of oldest vehicles, number of vehicles sold in past years, vehicles type	29
	Travel purpose: Number and type of trips in past days (e.g., run errands, pick up kids from soccer practice	10
	Attitude towards transport mode: Car ownership/use, use of public transport, walking, cycling, supporting car-free environment	17
	Frequency of travel mode use: Commonly used/preferred mode of transport, rideshare usage/sharing trips, driving habit, access to car-sharing, drive alone (for work trips)	40
	Medical condition: Having medical condition/disability that prohibits driving, intensity of disability, visual and physical impairment	10
	Accident involvement: involvement in accidents, citation record	15
	Driving mileage: number of kilometres/miles driven (in the last 12 months)	14
	Trust: Trusting automated vehicles, being comfortable with idea of removing steering wheel, being comfortable with travelling in an AV/with sending an AV on its own, believing that AV drives better than human driver, being concerned about riding in Avs, trusting technology companies	49
	Technology savviness: innovativeness, number and types of technologies used (e.g., owning smartphones) technology interest, technology readiness, curiosity, attitudes to robot approval, enthusiasm for technology,	34

Personality	knowledge of mobility-related developments, technological optimism and faith in progress, technological openness, being comfortable with technology	
	Control: Internal and external locus of control, preference to have control over things, having the option of manual drive, autonomy preference, desire for control preference for presence and responsibilities of bus operator/steward/supervisor, camera, interactive screen for communication with bus operator and visualisation of what AV sees	36
	Sharing AVs: Ability to interact with individuals outside immediate social circle, being concerned about sharing an automated vehicle with strangers, comfort with other drivers behind the wheel	10

Sources: Gkartzonikas et al. (2022)[49]; Acheampong and Cugurullo (2019)[50]; Li et al., (2022)[51]; Zhang and Kamargianni (2022)[52]; Othman (2021)[53]; Yuen et al., (2020)[54]; Yuen et al., (2020)[55]

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Annex 3. Model validation tests

A3.1 Reliability of scales in behavioural model Stage one

A3.1.1 Scale Environmental risk perception

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
,907	14

A3.1.2 Scale Outcomes of engaging in energy citizenship

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
,936	9

A3.1.3 Scale Norms supporting the engaging in energy citizenship

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
,931	8

A3.1.4 Scale agency to engage in energy citizenship

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

Reliability Statistics

Cronbach's Alpha	N of Items
,951	10

A3.1.5 Scale of Relational Model shift

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
,756	4

A3.1.6 Scale of energy citizenship Emotion

Case Processing Summary

		N	%
Cases	Valid	9414	89,8
	Excluded[a]	1074	10,2
	Total	10488	100,0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
,854	8

A3.2 Structural validity (whole survey sample 9300 observations)

Citizen engagement drivers	Constructs 1	2	3	4	5	6
ENR_C1 Controllability	-,028	-,009	**,682**	,098	,055	-,039
ENR_C2 Consequences (nonfatal – fatal)	,030	,097	**,773**	,070	-,019	-,098
ENR_C3 Distribution of effects (local – global)	,013	,049	**,745**	,050	,016	-,073
ENR_C4 Catastrophe level	,002	,056	**,795**	,020	,018	-,074
ENR_C5 Intergenerational effects	,008	-,039	**,729**	,080	,010	-,011
ENR_C6 Voluntariness of exposure	-,026	,014	**,786**	,011	,003	-,043
ENR_C7 Effects on the individual	,021	,038	**,773**	,049	-,091	-,030
ENR_C8 Observability	,007	,036	**,776**	-,006	-,024	-,049
ENR_C9 Knowledge of exposure	,007	-,021	**,774**	-,002	,006	-,065
ENR_C10 Discounting in space	-,006	-,081	**,616**	-,029	,151	,062
ENR_C11 Temporality of effects	,056	,048	**,728**	-,083	,010	,003
ENR_C12 Risk novelty	,010	,069	**,696**	-,050	,057	-,037
ENR_C13 Certainty of effects	,021	,016	**,621**	-,052	,006	,058
ENR_C14 Treat	,015	,069	**,710**	,000	-,045	-,051
OUT_C1 Safety	,145	**,774**	,039	,246	,038	-,039
OUT_C2 Emissions and environment	,149	**,781**	,040	,265	,031	,016
OUT_C3 Regulation compliance	,164	**,803**	,010	,232	,053	,044
OUT_C4 Comfort and convenience	,147	**,819**	,016	,229	,085	,003
OUT_C5 Individual economy	,166	**,789**	,072	,201	,116	,024
OUT_C6 Individual autonomy	,163	**,785**	,017	,209	,074	-,038
OUT_C7 Participation in the community	,151	**,792**	,034	,250	,060	-,004
OUT_C8 Individual health	,147	**,806**	,010	,228	,062	,034
OUT_C9 Individual internet privacy	,121	**,731**	-,004	,210	,009	,042
SN_C1 Family	,206	,369	,032	**,671**	,080	-,067
SN_C2 Partner	,206	,390	,039	**,662**	,080	-,060
SN_C3 Friends	,213	,370	,024	**,728**	,090	-,031
SN_C4 Local government	,166	,284	,046	**,839**	,124	,018
SN_C5 Regional government	,158	,259	,021	**,836**	,128	,017
SN_C6 National government	,165	,216	-,003	**,828**	,135	,023
SN_C7 European regulation	,157	,269	,000	**,807**	,092	,007
SN_C8 Associations and business	,151	,248	-,001	**,796**	,113	,028
AG_C1 Knowledge	**,812**	,091	-,014	,109	,107	-,035
AG_C2 Collaborative capacity	**,799**	,214	,026	,137	,088	-,024
AG_C3 Financial resources	**,837**	,097	-,008	,139	,138	-,004
AG_C4 Knowledge on funding sources	**,854**	,096	,010	,118	,120	,017
AG_C5 Knowledge on regulations	**,868**	,067	,000	,149	,130	,012
AG_C6 Availability of time to engage	**,836**	,181	,002	,141	,092	-,031
AG_C7 Trust on technical solutions	**,844**	,196	,020	,145	,076	-,020
AG_C8 Trust on business	**,815**	,174	-,008	,141	,114	,027
AG_C9 Trust on government	**,803**	,102	-,012	,147	,160	,020
AG_C10 Legacy system lock-in	**,780**	,181	,032	,130	,142	,019
RM_CB_Now Current RM with business	-,025	,063	-,055	,058	-,025	**,689**
RM_CB_Shift Ideal RM with business	,015	-,064	-,075	,021	,084	**,751**
RM_CG_Now Current RM with government	-,018	,105	-,062	-,014	,004	**,707**
RM_CG_Shift Ideal RM with government	,050	-,046	-,078	-,037	,089	**,729**
EM1 ...good	,245	,491	,103	,137	**,433**	-,328
EM2 ...proud	,221	,469	,075	,123	**,535**	-,288
EM3 ...worthwhile	,235	,478	,098	,131	**,514**	-,310
EM4 ...satisfied	,252	,478	,054	,088	**,508**	-,307
EM5 ...bad	,163	,027	-,003	,127	**,835**	,136
EM6 ...guilty	,173	,039	,021	,084	**,873**	,097
EM7 ...pointless	,141	-,029	,020	,136	**,856**	,123
EM8 ...remorseful	,129	,036	,005	,113	**,854**	,044

N=9300 cases
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization, rotation converged in 6 iterations.

Component	Extraction Sums of Squared Loadings Total	% Variance	% Cumulative	Rotation Sums of Squared Loadings Total	% Variance	% Cumulative
1_AG	15,153	27,059	27,059	7,976	14,243	14,243
2_OUT	7,548	13,479	40,538	7,826	13,974	28,217
3_ENR	4,989	8,910	49,447	7,556	13,493	41,710
4_SN	3,276	5,850	55,297	5,852	10,450	52,159
5_EM	2,777	4,959	60,256	4,264	7,615	59,774

6_RM	2,298	4,104	64,360	2,568	4,586	64,360

A3.3 Content validity

The two tables below present a regression analysis of Engagement withing the next five years and in the long term. The independent variables are the direct measures in each scale included in the questionnaire. These variables were captured and measured at the end of each scale for all the scales with exception of "emotion" that did not include such question. The question were intended to capture the whole conative loading of all the questions included in the scales. The results displayed in the tables support the validity of the model as the engagement of citizens can be explained in terms of a linear combination of the constructs proposed by the model in Deliverable D.1.1.

ENG 5Y regression

	R	R2	Adj. R2	SEE	
	0,481	0,232	0,229	1,767	
	Sum of Squares	df	Mean Square	F	Sig.
Regression	1811,73	6	301,96	96,66	<,001[9]
Residual	6013,44	1925	3,12		
Total	7825,17	1931			
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1,05	0,19		5,46	0,000
Capacities and resources currently	0,23	0,04	0,20	5,52	0,000
Expected outcomes in five years	0,15	0,03	0,12	4,91	0,000
Current RM with business	-0,18	0,04	-0,10	-4,46	0,000
Social support currently	0,11	0,03	0,09	3,52	0,000
Capacities and resources in five years	0,14	0,04	0,11	3,18	0,002
Ideal RM with business	-0,11	0,04	-0,06	-2,84	0,005

a. Dependent Variable: CCAM_ENG Within the next five years

ENG LT regression

	R	R2	Adj. R2	SEE	
	0,275	0,075	0,074	0,789	
	Sum of Squares	df	Mean Square	F	Sig.
Regression	2095,19	7,00	299,31	92,32	<,001
Residual	6238,07	1924,00	3,24		
Total	8333,26	1931,00			
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1,22	0,24		5,116	0,000
Capacities and resources in long term	0,34	0,03	0,29	11,278	0,000
Expected outcomes in five years	0,17	0,03	0,13	5,344	0,000
Current RM with government	-0,12	0,05	-0,06	-2,525	0,012
Ideal relational model with business	-0,11	0,04	-0,06	-2,624	0,009
Social support in the long term	0,10	0,03	0,08	2,880	0,004
Env risk within the next five years	0,24	0,09	0,05	2,639	0,008
Current RM with business	-0,10	0,04	-0,05	-2,231	0,026

a. Dependent Variable: CCAM_ENG in the longer term

What worth noticing is that almost all variables included in the model hold a positive relationship with the expected engagement of citizens within the next five years and in

the long term. The exception to this is the negative relationship with the current dominant relational model with business and government. This points out to the need to further explore the dynamics between actors and the social models that rule such interaction as these seems to go in detriment of the citizens engagement in the adoption and use of CCAM in the future. This in turn affecting the engagement in the clean energy transition. Furthermore, in both temporal assessment of engagement the role of citizens agency is the most significant explanatory variable of engagement. This is followed by the perception of environmental impacts.