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Deliverable Author(s)	Ioannis Pragidis (DUTH), Georgios Geronikolaou (DUTH), Paris Alexandros Karypidis(DUTH), Fotios Mitropoulos (DUTH), Vaso Kotsirou (DUTH), Paul Liston (TCD), Emma Delemere (TCD), Francesco Careri (JRC), Tilemahos Efthimiadis (JRC), Dan-Eric Archer (CW), Peter Rosengren (CW)
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Name	Institution	Date
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Acronyms

Acronym	Explanation
ALP	Rand American Life Panel
FINRA	Financial Capability Study
FR	Federal Reserved
FSSES	Financial Self-Efficacy Scale
GSES	Generalized self-efficacy scale
OECD	Organisation for Economic Co-operation and Development
OECD/INFE	Organisation for Economic Co-operation and Development / International Network on Financial Education
PIV	Private Investment Funds
PSX	Pakistan Stock Exchange
SCF	Survey of Consumer Finances
US HRS	United States Health and Retirement Study
WTP	Willingness to Pay

Executive Summary

This deliverable presents the main biases that may affect decision-making in energy efficiency. It then analyses the concepts of financial and environmental literacies and following the related literature proposes tools for assessing their level. Finally, proposes the design of a quasi-experiment that estimates how consumers respond to average and marginal prices taking into account the potential presence of biases as well participants' financial and environmental literacy level. Overall, results could assess the heterogeneity of responses to attributes such as age, education, existing biases, financial and environmental literacy level. Policy recommendations based on the main findings of the quasi-experiment may further boost consumers' energy efficiency and help narrow the energy efficiency gap.

1. Purpose and Overall Structure of the Deliverable

1.1 Purpose of the Deliverable

The purpose of this deliverable is to identify, describe and present behavioural biases that are related to energy consumption. For example, inattention, present bias, and overconfidence may have an impact on consumers decision-making that lead to inferior choices with respect to their welfare. Although the literature has been extensively examining the presence of biases and their effects, still some work is needed for determining their origins and most importantly whether policy actions could mitigate their effects. To this end, financial literacy is a crucial factor for the presence or not of biases. For example, an agent's low financial literacy level may amplify the magnitude of the overconfidence and risk-taking biases. In the same vein, environmental literacy emerges in recent year as a decisive factor that affects decision-making in energy consumption. With environmental challenges becoming more difficult and complex, significant skills are needed to understand and critically analyse these topics.

This deliverable will describe biases, ways for assessing the financial and environmental literacy levels and will propose experimental methods for assessing their combined impact on energy related topics. It will provide the framework for implementing part of use cases 4 and 5 (titled, "Relation of energy consumption behavioural biases with consumers' financial literacy level" and "Exploit energy demand curves" respectively). Specific surveys and a quasi-experiment will be designed in order to be used in other analyses in the EVIDENT project.

1.2 Relation with other Deliverables and Tasks

This deliverable will provide inputs to WP2 "Policy interventions and policy design", WP3 "Intervention preparation and execution" and to WP6 "Prototyping and integration". It also contributes partly to the implementation of use cases 4 and 5.

1.3 Structure of the Document

This deliverable is structured as follows:

Section 2: Introduction - This section provides an overview of the deliverable.

Section 3: The concept of financial literacy and its assessment tools – This section provides an overview of available assessment tools for financial literacy and presents core biases related to decision-making in the energy market. Finally, it proposes a financial literacy test to be implemented in the EVIDENT project.

Section 4: The concept of environmental literacy and its assessment tools – This section overviews the environmental literacy concept and its impact on attitudes and decision-making. Finally, it proposes an environmental literacy test to be implemented in the EVIDENT project.

Section 5: Reconciling financial and environmental literacy through a quasi-experiment – This section proposes a quasi-experiment for assessing the magnitude of the average price bias. Both financial and environmental literacies will be used for determining the driving factors for such a bias.

2. Introduction

Behavioural biases have been empirically tested that play an important role in the decision-making process. This can be mostly related with the tendency of consumers to rely on shortcuts because of the constraints on time and mental capacity to process a large amount of information. A voluminous number of studies show that biases such as base rate fallacy, present bias, anchoring bias, and more, are not only present but also have a significant and more importantly a predictive impact on financial markets, and any economic decision in everyday life. In the energy sector, biases may affect the decision about whether to invest or not in more energy efficient appliances. Because these investments induce large upfront costs, while consumers benefit from low consumption in a period of time, biases and individual time preferences systematically influence willingness to invest for improving energy efficiency which ultimately lead to underinvestment or inferior optimal choices. Empirical evidence shows that as measured through product choices, required payback periods, and energy efficiency tax credit claims, the consumers' elicited average mean discount rate is almost 19 percent [151]. The estimated rate is much higher than the average rate that prevails in the market and it is usually used to estimate investments payback periods. This means that the greater the discount rate, the shorter the time horizon required for the investment to break even. Thus, improving energy conservation and efficiency is closely related to behavioural biases.

The next question is then how to mitigate behavioural biases and decrease their impact on decision-making. To this end, studies show that agents' financial literacy level is an important factor to be analysed. In simple terms, financial literacy is the ability to use knowledge and skills to effectively manage financial resources at a personal level. Assessing the level of consumers' financial literacy is a key component for understanding the driving forces of the decision-making and consequently for proposing successful strategies for energy consumption. However, it should be noted that it is also a demanding and compelling endeavour.

Beyond biases and financial literacy, the environmental literacy concept has also emerged in latest years, as a potential factor for optimal decision-making in energy related topics. More generally, environmental literacy is the ability to examine the state of the natural environment and to take action to maintain or restore the health of that environment. Thus, an individual's knowledge and awareness of the impact of their behaviour on the environment may have an impact on their decision of whether to adopt pro-environmental actions. However, more empirical research is required to specify the factors which mediate this behaviour-environmental literacy relation.

In the EVIDENT project, we consider all these factors in a unified concept for better understanding the driving forces of the energy efficient gap and to propose specific policy actions. In doing so, we design a quasi-experiment related to average price bias and we will try to estimate how literacy levels and biases are interconnected. The average price bias is related to consumers' misperception regarding marginal prices. In some settings, for example in energy consumption, marginal prices can be induced for making people to switch consumption between peak and off-peak periods for protecting the electricity grid from possible disruptions. This nonlinear pricing scheme complicates economic decisions by creating multiple marginal prices for the same service. Despite its importance, this topic has not attracted much attention in the empirical research for the energy sector. Most studies focus on consumers' willingness to pay (WTP) for energy efficient products.

The proposed quasi-experiment will be implemented through the EVIDENT's platform, and will combine questions for eliciting consumers' biases, and their financial and environmental literacy level. Finally, the

participant will be asked to select among different pricing schemes that include simple and more complex non-linear prices for energy consumption.

Through this quasi-experiment we will get some proxy estimations about the potential drivers of the observed heterogeneity in consumers' price misperceptions. Results could be then used for specific policy recommendations.

3. The concept of financial literacy, main biases and their assessment tools

When the ability to make wise financial decisions is questioned, financial literacy is a crucial point to be considered. While one of the most critical factors, financial knowledge is not the only one since biases and heuristics also seem to affect this process. Although the traditional view in economics and finance suggests that only the outcomes matter, there is a strong debate about behavioural biases and the fact that rational scepticism cannot eliminate all these effects.

The rest of the section presents the fundamental cognitive biases on the process of decision making that we consider as relevant in the energy market and the concept of financial literacy, and finally, their assessment toolkits. At the end of this section, the EVIDENT financial literacy assessment tool, a questionnaire-based toolkit consisting of 18 items, is presented trying to interpret people behaviours and decisions by using their financial and technological knowledge levels as explanatory variables.

3.1 Key biases and their related questionnaires

Cognitive biases refer to systematic errors in thinking that occur when people process and interpret information in the world around them affecting their decisions and judgments. Thus, cognitive biases are a significant factor in decision-making and combined with low financial literacy levels, may lead to irrationality during the financial decision-making process. Section 3.1.1 presents the cognitive reflection test (CRT), a simple measure of one type of cognitive ability. At the same time, the rest subsections (3.1.2 – 3.1.8) are devoted to reviewing the most common behavioural biases related to financial decision-making and relevant research made.

3.1.1 Cognitive reflection test (CRT)

The Cognitive Reflection Test (CRT), initially presented by Frederick in 2005 [1] was designed to measure the tendency to override a prepotent response alternative that is incorrect and to engage in further reflection that leads to the correct response [2]. The CRT consists of a three-item test. Frederick (2005) argues that the CRT estimates more accurately the relationship between test scores and realized behaviour with respect to more complex personality tests. To account for any differences between more impulsive and more reflective responders, each question of the three-item CRT has a seemingly intuitive (but incorrect) answer that quickly comes in mind. Based on the findings, most of the participants indeed provide either the impulsive or the correct response (the estimated number is around 90% of the participants in all three questions). Its appealing feature is that CRT questions are not difficult to answer, and they could be easily comprehended when explained to the subjects. However, it assesses individuals' ability to suppress an intuitive and spontaneous wrong answer favouring a reflective and deliberative correct answer.

CRT has been broadly used as a proxy of performance on heuristics-and-biases tasks literature. In 2005 Frederick [1] used the CRT to examine its relationship with two crucial decision-making characteristics: time preference and risk preference. In addition, Toplak, West, & Stanovich (2011) [2] proved that the CRT is a more accurate indicator of performance on a broad number of tasks from the related biases literature than measures of cognitive ability, such as thinking dispositions, and executive functioning. Considering that potential participants may be becoming familiar with the original CRT three-item test, in

2014, Toplak, West, & Stanovich [3] provided an expansion of Frederick’s CRT. They examined an alternative four-item version, showing a close correlation with the original version providing a substitute for the original one. Moreover, they proposed a combined version with all seven questions providing a robust independent predictor of performance on analytical thinking tasks.

In Table 1 – Panel A, Frederick’s initial three-item test is presented while the extended version by Toplak, West and Stanovich can be found in Table 1 – Panel B.

Table 1: Cognitive reflection test questions

Question	Answers
Panel A: Frederick’s cognitive reflection test [2]	
1. A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? _____ cents	Integer number between 0 and 100. [correct answer 5 cents; intuitive answer 10 cents]
2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? _____ minutes	Integer number between 0 and 100. [correct answer 5 minutes; intuitive answer 100 minutes]
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? _____ days	Integer number between 0 and 100. [correct answer 47 days; intuitive answer 24 days]
Panel B: Expansion of the Cognitive Reflection Test by Toplak, West, & Stanovich (2014) [3]	
4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together? _____ days	Integer number between 0 and 100. [correct answer 4 days; intuitive answer 9]
5. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class? _____ students	Integer number between 0 and 100. [correct answer 29 students; intuitive answer 30]
6. A man buys a pig for \$60, sells it for \$70, buys it back for \$80, and sells it finally for \$90. How much has he made? _____ dollars	Integer number between 0 and 100. [correct answer \$20; intuitive answer \$10]
7. Simon decided to invest \$8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has:	One of the following options: a) broken even in the stock market b) is ahead of where he began c) has lost money [correct answer c, because the value at this point is \$7,000; intuitive response b]

3.1.2 Overconfidence

Overconfidence can be effectively defined as the tendency to overestimate the possibility of achieving a goal due to the self-righteous belief that one's own abilities or attributes may be used to bring about a specific result [4]. The overconfidence effect is a well-established behavioural bias in which people subjective confidence in their judgments is reliably larger than the objective accuracy of these judgments, especially when confidence is relatively high. However, greater confidence does not necessarily mean greater accuracy. In the investments and behavioural finance domain, overconfidence may lead individuals to overestimate their abilities and make risky investments. Overconfidence tends to make individuals less cautious in their decisions since many of these mistakes stem either from an illusion of knowledge or an illusion of control.

On an empirical basis, overconfidence bias has been broadly studied. Oechssler, Roider, & Schmitz, (2009) [5] find that the higher the test scores on the CRT, the lower the probability of presence of high rates of the conjunction fallacy, conservatism in updating probabilities, and overconfidence. The research uses a questionnaire with several decision problems combined with the CRT. In the case of the overconfidence bias, the researchers requested the subjects to estimate the number of questions on the CRT that they believed that had answered correctly. In an empirical application, Ahmad & Shah, in 2020 [6], showed how the overconfidence bias affected the performance of individual investors on the Pakistan Stock Exchange (PSX) after controlling for the mediating role of risk perception and financial literacy. Their questionnaire consists of six sections, while section C regarding overconfidence bias consists of sixteen questions divided into three facets: over-precision, overestimation, and over-placement. Based on their findings, they suggest that overconfidence is significantly negatively associated with poor investment decision-making. In addition, Montier (2006)[7] managed to scale behavioural biases for over 300 professional fund managers through a seventeen-item questionnaire. Based on his findings, the most common bias across the fund manager is over-optimism. Taylor & Brown (1988) [8] suggests that overconfidence and over-optimism biases are closely related and likely to appear jointly.

Table 2, presents the questions and the type of overconfidence bias collected from relevant studies. The table contains the types of over-precision (Table 2 – Panel A), over-placement (Table 2 – Panel B) and over-estimation (Table 2 – Panel C) as proposed by Odean, (1999) [9] and Barber & Odean (2000) [10].

Table 2: Overconfidence bias questions

Question	Answers	Source
Panel A: Questions related with the over-precision		
1. What do you think, how many of the CRT questions did you answer correctly?	A number between 0 and 3. [0,1,2,3]	[5]
2. Are you actively involved in trade activity?	One of the following options: a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree	[6]
3. Do you make investments to make money quickly?	One of the following options: a) Strongly disagree	[6]

		<ul style="list-style-type: none"> b) Disagree c) Somewhat agree d) Agree e) Strongly agree 	
4.	Do you make riskier investments for enjoyment?	One of the following options: <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree 	[6]
Panel B: Questions related with the over-placement			
1.	Do you believe that more or less than 10% of all participants answered all three [CRT] questions correctly?	One of the following options: <ul style="list-style-type: none"> a) More b) Less 	[5]
2.	Do you believe that more or less than 60% of all participants answered all three [CRT] questions correctly?	One of the following options: <ul style="list-style-type: none"> a) More b) Less 	[5]
3.	What do you think, is the percentage of participants who answered all three CRT questions correctly?	Integer number between 0 and 100.	[5]
4.	Do you believe that you have a better investment record with regard to others?	One of the following options: <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree 	[6]
5.	Do you have a better investment record as compared to others?	One of the following options: <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree 	[6]
Panel C: Questions related with the over-estimation			
1.	Do you believe that your skills and knowledge of stock market can help you to outperform the market?	One of the following options: <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree 	[6]
2.	Are you confident of your ability to do better than others in picking stocks?	One of the following options: <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree 	[6]

		e) Strongly agree	
3.	Do you have control of your investment decisions?	One of the following options: a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree	[6]
4.	Are you above average at your job?	One of the following options: a) Yes b) No	[7]

3.1.3 Conservatism bias

Conservatism bias refers to a mental process in which people insist on their prior beliefs or perceptions even new contradictory information arrives. This means that conservatism bias causes agents to overweight prior rates and on the other hand to underreact to new evidence. Thus, individuals are not able to timely react in a rational way when new information arrives [11]. In the financial world, conservatism can mean that the investor may be slow to respond to new data or events, compromising their judgement. An important distinction should be made between conservatism bias and representativeness bias since it's rather usual for people to exhibit both biases simultaneously. However, representativeness bias refers to over-reacting to the latest information, while conservatism bias refers to under-reacting to new information.

For example, conservatism bias might reflect a price trend as investors progressively incorporate new information, resulting in a slow adjustment of prices back to their underlying values. An additional example initiates from the concept of representativeness. Representativeness is a type of behavioural bias that leads investors to erroneously conclude that a pattern that has been established will continue well into the future. However, most of the time, these conclusions are based on a small sample of new information.

Behavioural finance studies shows that conservatism bias is part of "belief perseverance". It has consequences for complex information situations where there's an expectation or onus to absorb new information and adjust. Edwards in 1968 [12] , through an experiment he managed to illustrate the technical side of conservatism bias eloquently. Edwards suggested that people updated beliefs conservatively, following Bayes' theorem more slowly. Pompian (2012) [11] set up his conservatism bias test consisting of three simple questions suggesting that objects that select answers indicating slower adaptation to new information may indicate susceptibility to conservatism bias.

Table 3, presents the questions about conservatism bias collected from relevant studies.

Table 3: Conservatism bias questions

Question	Answers	Source
1. Imagine there are two urns - urn A and urn B. Urn A contains 3 blue balls and 7 red balls. Urn B contains 7 blue balls and 3 red balls. Balls are now randomly	Either decimal number between 0 and 1 or integer number between 0 and 100.	[12]

<p>drawn from one of these urns where the drawn ball is always placed back into the same urn. Twelve such random draws yielded 8 red balls and 4 blue balls. What do you estimate the probability that the balls were drawn from urn A?</p> <p>or similarly,</p> <p>There are two bookbags, one containing 700 red and 300 blue chips, the other containing 300 red and 700 blue. Take one of the bags. Now, you sample, randomly, with replacement after each chip. In 12 samples, you get 8 reds and 4 blues. what is the probability that this is the predominantly red bag?</p>	<p>[correct answer 0.97; intuitive response closer to the base rate of 0.5]</p>	
<p>Suppose that you live in Baltimore, MD, and you make a forecast such as, "I think it will be a snowy winter this year." Furthermore suppose that, by mid-February, you realize that no snow has fallen. What is your natural reaction to this information?</p>	<p>One of the following options:</p> <ul style="list-style-type: none"> a) There's still time to get a lot of snow, so my forecast is probably correct. b) There still may be time for some snow, but I may have erred in my forecast. c) My experience tells me that my forecast was probably incorrect. Most of the winter has elapsed; not much snow, if any, is likely to arrive now. 	<p>[11]</p>
<p>When you recently hear news that has potentially negative implications for the price of an investment you own, what is your natural reaction to this information?</p>	<p>One of the following options:</p> <ul style="list-style-type: none"> a) I tend to ignore the information. Because I have already made the investment, I've already determined that the company will be successful. b) I will re-evaluate my reasons for buying the stock, but I will probably stick with it because I usually stick with my original determination that a company will be successful. c) I will re-evaluate my reasoning for buying the stock and will decide, based on an objective consideration of all the facts, what to do next. 	<p>[11]</p>
<p>When news comes out that has potentially negative implications for the price of a stock that you own, how quickly do you react to this information?</p>	<p>One of the following options:</p> <ul style="list-style-type: none"> a) I usually wait for the market to communicate the significance of the information and then I decide what to do. b) Sometimes, I wait for the market to communicate the significance of the 	<p>[11]</p>

	information, but other times, I respond without delay. c) I always respond without delay.	
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3.1.4 Anchoring bias

Anchoring (or anchoring bias) refers to people's propensity to estimate the possibility of an uncertain event or either predict or recall a specific value or result by considering the initial value and adjusting it up or down to draw conclusions [13]. Anchoring and adjustment is a psychological-related bias that affects the way people estimate and consider probabilities.

For example, investors who exhibit anchoring bias are usually influenced by buying "signals" or arbitrary starting price levels or price indices, and when it comes to decisions about buying/selling assets or estimate the market trends they tend to cling to these points. In the process of decision-making, rational investors are expected to be less affected by anchoring bias since they react more rationally to new information and do not reflect on arbitrary purchase or target prices. However, anchoring and adjustment bias implies that investors elaborate new information in a sluggish and many times in false way [11]. Another example shows that buyers may be more likely to purchase a car if it is placed alongside a more expensive model (the anchor).

Gregory Northcraft and Margaret Neale, in 1987 [14], performed a research experiment about the effects of anchoring and adjustment. They asked a group of real estate professionals to value a listing after being given a proposed selling price quoted by the researchers at the experiment's outset. Based on their analysis, it's clear that anchoring bias is widespread, applying to many areas of finance and business decision-making. Moreover, Kudryavtsev & Cohen (2011) [15] tried to analyse the role of the anchoring bias in perceiving economic and financial information. In their experimental procedure, the participants had to recall several recent economic and financial indicators; however, they provided them with unrelated economic or financial indicators ("anchor indicators") before each question. Their results showed that, on average, each of their experimental questions and the vast majority of participants showed significant anchoring bias.

Table 4, questions related to the anchoring bias collected from relevant studies can be found.

Table 4: Anchoring bias questions

Question	Answers	Source
1. The current value of S&P 500 Index is 1172 points. I suppose that the current value of TA-25 Index is _____.	Integer number larger or equal than 0.	[1]
2. The S&P 500 Index annual return in 2009 was 23.45%. I suppose that the TA-25 Index annual return in 2009 was _____%.	Integer number between 0 and 100.	[1]
3. The average annual return of S&P 500 Index over the years 2007-2009 was -7.70%. I suppose that the average annual return of TA25 Index over the years 2007-2009 was _____%.	Integer number between 0 and 100.	[1]

4.	The current value of S&P 500 Index differs from the Index's historical high by 25.11%. I suppose that the current value of TA25 Index differs from the Index's historical high by _____%.	Integer number between 0 and 100.	[1]
5.	The manufacturing production in Israel increased in 2008 relatively to 2007 by 7.39%. I suppose that the TA-100 Index annual return in 2009 was _____%.	Integer number between 0 and 100.	[1]
6.	The average annual rate of increase in the manufacturing production in Israel over the years 1998-2008 was 3.55%. I suppose that the average annual return of TA-100 Index over the years 2007-2009 was _____%.	Integer number between 0 and 100.	[1]
7.	The major increase in the manufacturing production in Israel in the last decade took place in 2000. The manufacturing production increased by 9.88%. I suppose that the current value of TA-100 Index differs from the Index's historical high by _____%.	Integer number between 0 and 100.	[1]
8.	The DAX Index annual return in 2009 was 23.85%. I suppose that the Mid-Cap-50 (Yeter 50) Index annual return in 2009 was _____%.	Integer number between 0 and 100.	[1]
9.	The current value of DAX Index differs from the Index's historical high by 23.71%. I suppose that the current value of Mid-Cap-50 (Yeter 50) Index differs from the Index's historical high by _____%.	Integer number between 0 and 100.	[1]
10.	The agricultural output in Israel increased in 2008 relatively to 2007 by 7.45%. I suppose that the Tel-Bond 20 Index annual return in 2009 was _____%.	Integer number between 0 and 100.	[1]
11.	The agricultural output in Israel increased in 2008 relatively to 1998 by 16.28%. I suppose that the current before taxes 5-years yield to maturity on Galil (CPI-linked fixed rate) government bonds is equal to _____%.	Integer number between 0 and 100.	[1]
12.	The major increase in the agricultural output in Israel in the last decade took place in 2004. The agricultural output increased by 10.1%. I suppose that the current before taxes 5-years yield to maturity on Shahar (non-linked fixed rate) government bonds is equal to _____%.	Integer number between 0 and 100.	[1]
13.	The inflation rate in the US in from the beginning of this year is 1.8%. I suppose that the inflation rate in Israel from the beginning of this year is _____%.	Integer number between 0 and 100.	[1]
14.	The inflation rate in the US in 2009 was 2.7%. I suppose that the inflation rate in Israel in 2009 was _____%.	Integer number between 0 and 100.	[1]
15.	The average annual inflation rate in the US over the years 2007-2009 was 2.29%. I suppose that the average annual	Integer number between 0 and 100.	[1]

	inflation rate in Israel over the years 2007-2009 was _____%.		
16.	The gross domestic product of Israel increased in 2008 relatively to 2007 by 2.2%. I suppose that the current Interest Rate of Bank of Israel is equal to _____%.	Integer number between 0 and 100.	[1]
17.	The gross domestic product of Israel increased in 2006 relatively to 2005 by 3.4%. I suppose that the current Prime Interest Rate is equal to _____%.	Integer number between 0 and 100.	[1]
18.	The Yen/Shekel exchange rate changed from the beginning of this year by -0.45%. I suppose that the Dollar/Shekel exchange rate changed from the beginning of this year by _____%.	Integer number between 0 and 100.	[1]
19.	The Yen/Shekel exchange rate changed over the year 2009 by -3.66%. I suppose that the Dollar/Shekel exchange rate changed over the year 2009 by _____%.	Integer number between 0 and 100.	[1]
20.	The Dollar-to-British Pound exchange rate (Dollars for 1 Pound) changed from the beginning of this year by -6.67%. I suppose that the Euro/Shekel exchange rate changed from the beginning of this year by _____%.	Integer number between 0 and 100.	[1]
21.	The Dollar-to-British Pound exchange rate (Dollars for 1 Pound) changed over the year 2009 by -9.13%. I suppose that the Euro/Shekel exchange rate changed over the year 2009 by _____%.	Integer number between 0 and 100.	[1]
22.	Please write down the last four digits of your telephone number. Is the number of physicians in London higher or lower than this number?	One of the following options: a) Lower b) Higher	[2]
23.	Please write down the last four digits of your telephone number. What is your best guess as to the number of physicians in London?	Integer number larger than 0.	[2]

3.1.5 Tolerance to risk (risk preferences) and Risk aversion

Risk tolerance plays a crucial role in financial planning. Dalton & Dalton (2004) [16] define risk tolerance as “The level of risk exposure with which an individual is comfortable; an estimate of the level of risk an investor is willing to accept in his or her investment portfolio”. Risk tolerance (or risk preferences) is also associated with other behavioural attributes such as overconfidence, base rate fallacy and conservatism. In the domain of trading, risk tolerance is also closely correlated with martingale bias (when you lose, double the bet), impact bias (overestimate the significance of what you think may happen in the future) and regret theory bias (hold onto a losing asset for longer than a trader should do).

In economics and finance, risk aversion means that individuals tend to prefer low-uncertainty over high-uncertainty results, even if the latter’s average rate of return is equal to or higher than the monetary value

of more certain results [17]. Risk aversion explains the propensity of individuals to select situations with possible lower payoffs but more predictable and “safe” in the sense of results outcome, rather than situations where higher yields are probable but less guaranteed.

Questions concerning attitudes, current behaviour, and feelings have been extensively discussed in the literature related to composite risk tolerance measures [18]–[21]. The Federal Reserve (FR) has sponsored the Survey of Consumer Finances¹ (SCF), a cross-sectional survey of U.S. families which is repeated every three years. The survey data includes information about household balance sheets, pensions, income, and demographic characteristics, and since the first survey (1983), it has included questions about risk tolerance.

Table 5 presents questions of Risk Preferences and Risk aversion bias collected from relevant studies. Table 5 – Panel A contains questions regarding risk aversion while Table 5 – Panel B and C presents general risk tolerance questions and risk tolerance questions coming from Private Investment Funds (PIV) respectively.

Table 5: Questions related to the research of risk preferences and risk aversion

Question	Answers	Source	
Panel A: questions measuring risk aversion			
1.	Which of the following statements comes closest to describing the amount of financial risk that you are willing to take when you save or make investments?	One of the following options: a) Take substantial financial risks expecting to earn substantial returns b) Take above average financial risks expecting to earn above average returns c) Take average financial risks expecting to earn average returns d) Not willing to take any financial risks	FR
2.	Suppose that you are the only income earner in the family, and you have a good job guaranteed to give you your current income every year for life. You are given the opportunity to take a new and equally good job, with a 50-50 chance that it will double your income and a 50-50 chance that it will cut your income by one-third (33 percent). Would you take the new job?	One of the following options: a) Yes b) No	FR
3.	Now suppose that the chances were 50-50 that it would double your income and 50-50	One of the following options: a) Yes	FR

¹ <https://www.federalreserve.gov/econres/scfindex.htm>

	that it would cut your income by half (50 percent). Would you still take the new job?	b) No	
4.	Now suppose that the chances were 50-50 that it would double your income and 50-50 that it would cut your income by one-fifth (20 percent). Would you now take the new job?	One of the following options: a) Yes b) No	FR
5.	You have the choice between two alternatives. Alternative 1: You receive 10 euros. Alternative 2: You receive a lottery ticket that yields a 75% chance of winning 20 euros. With 25% probability it is worthless. Which alternative do you choose?	One of the following options: c) Alternative 1 d) Alternative 2	[5]
6.	You have to pay 10 euros. Would you rather replace this payment through the following alternative: With a probability of 75% you must pay 20 euros? With 25% probability you don't have to pay anything.	One of the following options: a) Yes b) No	[5]
7.	How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?	Scale from 0 to 10, where the value 0 means: 'unwilling to take risks' and the value 10 means: 'fully prepared to take risk'.	[22]
Panel B: questions measuring risk tolerance			
1.	Which of the following statements comes closest to the amount of financial risk that you are willing to take when you save or make investments	One of the following options: a) Take substantial financial risk expecting to earn substantial returns b) Take above average financial risks expecting to earn above average returns c) Take average financial risks expecting to earn average returns d) Not willing to take any financial risks	SCF
Panel C: questions measuring risk tolerance from Private Investment Funds (PIV)			
1.	I plan to begin taking money from my investments in . . .	One of the following options: a) 1 year or less b) 1 – 2 years c) 3 – 5 years d) 5 – 10 years e) 11 – 15 years f) More than 15 years	

2.	As I withdraw money from these investments, I plan to spend it over a period of . . .	<p>One of the following options:</p> <ul style="list-style-type: none"> a) 2 years or less b) 3 – 5 years c) 6 – 10 years d) 11 – 15 years e) More than 15 years
3.	When making a long-term investment, I plan to keep the money invested for . . .	<p>One of the following options:</p> <ul style="list-style-type: none"> a) 1 – 2 years b) 3 – 4 years c) 5 – 6 years d) 7 – 8 years e) More than 8 years
4.	From September 2008 through November 2008, stocks lost over 31%. If I owned a stock investment that lost about 31% in 3 months, I would: (If you owned stocks during this period, select the answer that corresponds to your actual behaviour.)	<p>One of the following options:</p> <ul style="list-style-type: none"> a) Sell all of the remaining investment. b) Sell a portion of the remaining investment. c) Hold onto the investment and sell nothing. d) Buy more of the Investment
5.	Generally, I prefer investments with little or no fluctuation in value, and I'm willing to accept the lower return associated with these investments.	<p>One of the following options:</p> <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree
6.	During market declines, I tend to sell portions of my riskier assets and invest the money in safer assets.	<p>One of the following options:</p> <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree
7.	I would invest in a mutual fund based solely on a brief conversation with a friend, co-worker, or relative.	<p>One of the following options:</p> <ul style="list-style-type: none"> a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree
8.	From September 2008 through October 2008, bonds lost nearly 4%. If I owned a bond investment that lost almost 4% in 2 months, I would: (If you owned bonds during this period,	<p>One of the following options:</p> <ul style="list-style-type: none"> a) Sell all of the remaining investment. b) Sell a portion of the

	select the answer that corresponds to your actual behaviour.)	remaining investment. c) Hold onto the investment and sell nothing. d) Buy more of the investment.
9.	When it comes to investing in stock or bond mutual funds (or individual stocks or bonds), I would describe myself as . . .	One of the following options: a) Very inexperienced b) Somewhat inexperienced c) Somewhat experienced d) Experienced e) Very experienced
10.	Am I comfortable investing in the stock market?	One of the following options: a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree
11.	When I put aside money for retirement, I do not plan on accessing it before I retire.	One of the following options: a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree

3.1.6 Base rate fallacy (Base rate neglect) - Representativeness

Base-rate fallacy refers to people’s tendency to neglect base rates favouring, e.g., distinguishing information rather than integrating the two. This tendency might extensively affect the understanding of judgment phenomena in clinical, legal, and social-psychological settings[23]. In other words, people's pre-existing ideas (stereotypes) seems to affect their judgement and perceive their probabilities even if the expected results seem to be statistically invalid. When new information is received, “rational” investors update those probabilities to reflect the given data; however, when subject to base rate fallacy, only a little care is given on the base rates (prior probabilities) and too much on the new information. The opposite effect also is a standard cognitive error, known as the conservatism bias (section 3.1.3), whereby the base rate is overly weighted.

Base rate fallacy bias may also lead to harmful effects since individuals rely on past, outdated, and inadequate statistical data that does not reflect the current status to make decisions. In terms of investing, the base rate fallacy (or the base rate neglect) may lead to overreaction or underreaction. Investors may

erroneously overact in a temporary downside movement of a stock, neglecting information about the stock's long-term trend.

For example,² Mike is an opera fan who also enjoys visiting art museums and other historic sites in his free time. Growing up, Mike liked also to play chess with friends, and his favourite musical was The Phantom of the Opera. Which situation is more likely?

- a) Mike plays the first violin for a major symphony orchestra
- b) Mike is a lawyer

Even if there are more probabilities for Mike being a lawyer, most people will incorrectly reply that Mike is a musician. Based on the given description and Mike's characteristics, it seems reasonable to be employed in the arts rather than law. However, the base rate fallacy can be easily disclosed by looking at some statistics. There are more than 1.5 million lawyers in America, rather only a few first-chair violinists for a major orchestra.

Hoppe and Kusterer (2009) [24] performed a large-scale quasi-experiment to explore whether subjects' cognitive ability (through CRT) are related to the base rate fallacy, and other biases such as overconfidence, conservatism bias, and endowment effect. Results showed that subjects with higher CRT scores are less prone to base rate fallacy bias and state the correct probability more often. In addition, Montier (2006) [7] discovered that judging things by how they appear rather than how statistically likely they are is a common bias among individuals.

Table 6 presents questions of base rate fallacy bias collected from relevant studies.

Table 6: Rate fallacy bias questions

Question	Answers	Source
1. In a city with 100 criminals and 100,000 innocent citizens there is a surveillance camera with an automatic face recognition software. If the camera sees a known criminal, it will trigger the alarm with 99% probability; if the camera sees an innocent citizen, it will trigger the alarm with a probability of 1%. What is the probability that indeed a criminal was filmed when the alarm is triggered?	Integer number between 0 and 100. [correct answer 9; intuitive response >90]	[24]
2. A group of police officers have breathalysers displaying false drunkenness in 5% of the cases in which the driver is sober. However, the breathalysers never fail to detect a truly drunk person. One in a thousand drivers is driving drunk. Suppose the police officers then stop a driver at random and force the driver to take a	Integer number between 0 and 100.	[24]

² Example taken from www.investopedia.com

	<p>breathalyser test. It indicates that the driver is drunk. We assume you don't know anything else about him or her. How high is the probability he or she really is drunk?</p>		
3.	<p>Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.</p> <p>Next, we ask you which of the following statements you think is more likely:</p>	<p>One of the following options:</p> <p>a) Linda is a bank teller</p> <p>b) Linda is a bank teller and is active in the feminist movement</p>	[25]
4.	<p>A health survey was conducted in a sample of adult males in New Jersey, of all ages and occupations. Please give your best estimates of the following values:</p> <p>What percentage of the men surveyed have had one or more heart attacks?</p> <p>What percentage of the men surveyed are both over 55 and have had one or more heart attacks?</p>	<p>Integer number between 0 and 100 for the “percentage of the men surveyed have had one or more heart attacks”.</p> <p>Integer number between 0 and 100 for the “percentage of the men surveyed are both over 55 and have had one or more heart attacks”.</p>	[7]
5.	<p>Suppose an unbiased coin is flipped three times, and each time the coin lands on heads. If you had to bet \$1000 on the next toss, what side would choose? Heads, tails or no preference?</p>	<p>One of the following options:</p> <p>a) Heads</p> <p>b) Tails</p> <p>c) No preference</p>	[7]
6.	<p>A student at a university has a Grade Point Average (GPA) of 3.8 in her first semester. The average GPA at the university is 3.1. What will be her GPA percentile when she graduates as a senior? (The better she does the higher the percentile...i.e. 100 would be the top people in the year).</p>	<p>Integer number between 0 and 100.</p>	[7]
7.	<p>Jim is an ex-college baseball player. After he graduated from college, Jim became a physical education teacher. Jim has two sons, both of whom are excellent athletes. Which is more likely?</p>	<p>One of the following options:</p> <p>a) Jim coaches a local Little League team.</p> <p>b) Jim coaches a local Little League team and plays softball with the local softball team.</p>	[11]
8.	<p>What is the probability that Company A (ABC, a 75-year-old steel manufacturer that is having some business difficulties) belongs to group B (value stocks that will likely recover) rather</p>	<p>Either decimal number between 0 and 1 or integer number between 0 and 100.</p>	[11]

	than to Group C (companies that will go out of business)?		
9.	What is the probability that AAA-rated Municipal Bond A (issued by an “inner city” and racially divided county) belongs to Group B (risky municipal bonds) rather than to Group C (safe municipal bonds)?	Either decimal number between 0 and 1 or integer number between 0 and 100.	[11]

3.1.7 Financial self-efficacy

Self-efficacy is connected to self-confidence, motivation and optimism, that one can cope with a range of life's obstacles. It's also referring to a sense of personal agency and the belief that one can achieve and succeed at a specific activity [26]. Every aspect of human endeavour is influenced by self-efficacy. For example, self-efficacy might influence a person's beliefs regarding their power to affect situations, their ability to face challenges and make choices. According to Bandura (1977) [27], individuals presenting higher levels of self-efficacy and confidence are willing to undertake more challenging tasks with a higher probability of success.

In the finance domain, financial self-efficacy is the confidence individuals have in accessing, using financial products or services, undertaking financial decisions, and dealing with complicated financial situations [28], [29]. According to Hejazi, Shahraray, Farsinejad, & Asgary, (2008) [30], self-efficacy contributes positively to the procedure of cognitive thinking to achieve the desired action driven by willpower apart from the skills individuals have endowed.

In 1995, Schwarzer and Jerusalem [31] developed a generalized self-efficacy scale (GSES), that consists by a ten-item scale to measure the individual’s belief in their own ability when it comes to handle and accomplish with new or difficult situations or deal with any associated obstacles or setbacks. Based on their findings, there is a negative relationship between stress, anxiety, depression, and burnout. Lown (2011) [32] developed a similar 6-item Financial Self-Efficacy Scale (FSES) based on Schwarzer and Jerusalem GSES, concluding that financial self-efficacy may differ from general self-efficacy.

GSES and FSES questions related to self-efficacy are presented in Table 7.

Table 7: Questions related to financial self-efficacy bias

Question	Answers	Source
1. I can always manage to solve difficult problems if I try hard enough.	One of the following options: a) Exactly true b) Moderately true c) Hardly true a) Not true at all	[31]– (GSES)
2. It is hard to stick to my spending plan when unexpected expenses arise.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]

3.	It is challenging to make progress towards my financial goals.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]
4.	When unexpected expenses occur, I usually have to use credit.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]
5.	I am confident that I could deal efficiently with unexpected events.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31]
6.	When faced with financial challenge, I have a hard time figuring out a solution	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]
7.	I lack confidence in my ability to manage my finances.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]
8.	I can solve most problems if I invest the necessary effort	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31]
9.	I worry about running out of money in retirement.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31], [32]
10.	I can remain calm when facing difficulties because I can rely on my coping abilities.	One of the following options: a) Exactly true b) Moderately true c) Hardly true d) Not true at all	[31]

3.1.8 Present bias (impatience)

When suffering from present bias, people will probably weigh more the payoffs that are closer to the present time rather than considering the trade-offs between two future moments [33].

As an example³, consider the following two choices:

Choice A: \$100 today over **Choice B:** \$110 in a week

Choice C: \$100 4 weeks over **Choice D:** \$110 in 5 weeks

Subjects in choice experiments often choose A (pay now) over B (pay later). This behaviour extends to other domains including primary rewards, showing that this choice pattern prevails in everyday decision making [34].

In finance, empirical research finds that present bias is associated with undesirable spending, borrowing, and saving behaviours. Research shows that present-biased consumers may spend too much [35], borrow too much [36], and save less [37], compared to other consumers. Present-biased consumers also exhibit fewer beneficial health behaviours [38]. O'Donoghue & Rabin (1999) [33] made two sets of distinctions: the first distinction is whether choices involve immediate costs while the second choices involve immediate rewards. In the first case, the costs of an action are immediate but any rewards are delayed while the benefits of an action are immediate, but any costs are delayed.

Table 8 presents questions relative to present bias collected from relevant studies, while Table 8 – Panel A contains generic questions about present bias while Table 8 – Panel B presents questions regarding “immediate rewards”/ “immediate costs”.

Table 8: Present bias questions

Question	Answers	Source
Panel A: generic questions regarding present bias		
1. I am impulsive and tend to buy things even when I can't really afford them.	One of the following options: a) Strongly Agree b) Agree c) Undecided d) Disagree e) Strongly Disagree	[39]
2. I intend to live in the present more and do not consider the future.	One of the following options: a) Totally inapplicable b) Somewhat inapplicable c) Generally applicable d) Somewhat applicable e) Totally applicable f) Don't know	[40]
Panel B: questions regarding “immediate reward”/ “immediate costs”		

³ Example taken from (Chakraborty, 2019)

1.	If you are one of the six winners who receive a prize for this questionnaire, you can pick between two alternatives. Which alternative do you choose?	One of the following options: a) We will transfer your winnings immediately after the end of the experiment b) We will transfer your winnings 1 month after the end of the experiment with a 10% premium.	[5]
2.	Would you prefer to receive \$100 today or \$153.80 in 12 months?	One of the following options: a) \$100.00 today b) \$153.80 in 12 months	[41]
3.	Would you prefer to receive \$120 in 12 months or \$184.60 in 24 months?	One of the following options: a) \$120.00 in 12 months b) \$184.60 in 24 months	[41]
4.	Do you think you would prefer to choose to receive \$110 on that day or \$169.20 in another 12 months?	One of the following options: a) \$110 on that day b) \$169.20 12 months later	[41]

3.2 Empirically assessing the financial literacy level

According to OECD INFE⁴, financial literacy is defined as:

“A combination of awareness, knowledge, skill, attitude and behaviour necessary to make sound financial decisions and ultimately achieve individual financial wellbeing.”

In other words, financial literacy refers to individuals' ability to understand and to manage their financial resources at an optimum level. This definition does not refer to just comprehend numbers and arithmetic sequences. Financial literacy implies consumers' ability to understand basic financial concepts such as the time value of money, the difference between real and nominal values, how compound interest rates operate, the meaning of inflation and its effects on borrowing, how to achieve financial diversification, and ultimately how to interpret financial data correctly.

In accordance to the above definition Lusardi and Mitchell (2014) [42], further argue that financial literacy could also include:

“...peoples' ability to process economic information and make informed decisions about financial planning, wealth accumulation, debt and pensions”.

Financial literacy research has traditionally linked people's knowledge of finance and economics to their decisions regarding financial issues, such as retirement planning, saving, and portfolio selection. Lusardi & Mitchell, in 2007 [43] aim to evaluate how successfully individuals make their retirement plans and how the subsequent accumulation of retirement wealth is associated with their financial literacy level. In their

⁴ OECD International Network on Financial Education - OECD/INFE (<https://www.oecd.org/financial/education/oecd-international-network-on-financial-education.htm>)

analysis they use two cohorts and compare in between differences in their accumulated retirement capital: the first cohort includes the early Baby Boomers in 2004 and the second cohort includes individuals in the same age group in 1992 and by using instrumental variables (e.g., net worth, wealth, etc.), they show that retirement planning preferences can explain the differences in savings and retirement plans. Gathergood (2012) [39] used household survey data (for example, consumer's credit market participation, portfolio analysis and payment problems) to examine whether there is a causal relationship regarding financial literacy, self-control, and credit over-indebtedness on UK consumers. Based on their findings, highly indebted consumers are more likely to suffer from financial illiteracy and lack of self-control. In a later study, Gathergood and Weber (2014) [44] use data coming from a UK survey to analyse the puzzling relationship between high-cost consumer credit alongside with households' low yield savings plans, which they name the 'co-hold puzzle'. Focusing on two different sources of behavioural biases: lack of self-control and poor financial literacy, they link consumers' high-cost credit with behavioural biases that affect their decision making.

Academic literature has seen several approaches for the assessment of the levels of financial literacy. The first approach follows Mandell (2004, 2008) [45], [46] and the second approach is based on the analysis of Lusardi & Mitchell (2007) [43]. Both approaches follow a quiz-type questions, installed either in custom-made or mainstream population surveys, such as large-scale and repetitive surveys conducted by international organizations like OECD, IMF, and the World Bank. Contrary to Lusardi and Mitchell's approach, Mandell's approach is based on long test-type quizzes which induced criticism due to the fact that a large number of questions is usually included. Furthermore, the criticism for Mandell's approach often focuses on questions lacked conceptual clarity that were often interrelated. This may result in conceptual and statistical shortcomings. Lusardi & Mitchell based their approach on sets of 3, 5, 7, or 17 questions characterized by simplicity and conceptual clarity. Due to its clarity and simplicity, their approach dominated the field. It should be noted that, the topics covered in the questionnaire focused on understanding the three fundamental notions of finance, namely, inflation effects, interest compounding, and portfolio diversification. Moreover, Lusardi & Mitchell (2011) [47] argue that while it is essential to assess the level of people's financial literacy, the assessment should be based only on four fundamental principles: brevity, relevance, simplicity, and the capacity to differentiate. They categorised the financial literacy questions into two pools, namely "basic" and "sophisticated" based on their complexity and difficulty to get answered correctly. An apriori assumption could be that sophisticated questions would induce a larger number of false answers.

The 2004 US Health and Retirement Study (HRS) were the first experimental financial literacy module in which the three questions from Lusardi's & Mitchell's financial literacy toolkit were introduced. Thenceforth many other consumer surveys, such as the National Longitudinal Survey of Youth (NLSY) for 2007-2008, the Financial Capability Study (FINRA) in 2010, the Rand American Life Panel (ALP) in 2008, use these questions (either solely or along) to assess participants' financial literacy level. The questions are included in Table 9 – Panel A. In addition, the World Bank has included this set of questions in a number of its own custom-made surveys. For each question, there is a 5 level Likert Scale of possible answers; however, there is only one correct answer. Participants can also refuse to answer a question or even choose "Don't know" as an option.

In more recent research Klapper, Lusardi, & Oudheusden (2015) [48] extend the three-item financial literacy questionnaire by distinguishing the concepts of interest rates and numeracy. The four financial literacy assessment questions are presented in Table 9 – Panel B.

In 2009, OECD presented the International Network on Financial Education (OECD/INFE) toolkit. INFE was based on OECD working paper by Kempson in 2009 [49], 1 national survey, international research and expert advice and built up a toolkit for measuring financial literacy and financial inclusion. The questions included in INFE were taken from existing surveys, and they have been successfully used to capture the financial literacy of diverse populations. INFE originates in 2010 where OECD implemented the first international exercise about financial literacy and financial inclusion measurement. The financial literacy questions used in INFE have all been validated and approved by OECD/INFE experts. OECD/INFE questions cover many categories, such as planning and managing finances and choosing and using financial products and refer to participants' attitudes, behaviours, and financial knowledge. Table 9 – Panel C includes a series of eight questions from the OECD's (2018) [50] latest endeavour to negotiate the same 3-4 fundamental concepts, namely interest, inflation, risk, and numeracy.

Finally, Table 9 – Panel D presents questions regarding financial literacy assessment from relevant publications such as Gathergood (2012) [39], Gathergood & Weber (2017) [51] and Lusardi & Tufano (2009) [52] already analysed in previous paragraphs.

Table 9: Financial literacy assessment questions

Question		Answers
Panel A: The 3 basic financial literacy assessment questions Lusardi & Mitchell (2014) [42]		
1.	<i>Numeracy [interest compounding]</i> Suppose you had \$100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?	One of the following options: a) More than \$102 b) Exactly \$102 c) Less than \$102 d) Do not know e) Refuse to answer
2.	<i>Inflation</i> Imagine that the interest rate on your savings account was 1 percent per year and inflation was 2 percent per year. After 1 year, how much would you be able to buy with the money in this account?	One of the following options: a) More than today b) Exactly the same c) Less than today d) Do not know e) Refuse to answer
3.	<i>Risk diversification</i> True or false? Buying a company stock usually provides a safer return than a stock mutual fund.	One of the following options: a) True b) False c) Do not know d) Refuse to answer
Panel B: The 5 extended financial literacy assessment questions by Klapper, Lusardi, & Oudheusden, (2015) [48]		
1.	<i>Numeracy [interest compounding]</i>	One of the following options:

	Suppose you need to borrow 100 US dollars. Which is the lower amount to pay back: 105 US dollars or 100 US dollars plus three percent?	a) 105 US dollars b) 100 US dollars plus three percent c) Do not know d) Refuse to answer
2.	<p><i>Inflation</i></p> <p>Suppose over the next 10 years the prices of the things you buy double. If your income also doubles, will you be able to buy less than you can buy today, the same as you can buy today, or more than you can buy today?</p>	One of the following options: a) Less b) The same c) More d) Do not know e) Refuse to answer
3.	<p><i>Compound interest 1</i></p> <p>Suppose you had 100 US dollars in a savings account and the bank adds 10 percent per year to the account. How much money would you have in the account after five years if you did not remove any money from the account?</p>	One of the following options: a) More than 150 dollars b) Exactly 150 dollars c) Less than 150 dollars d) Do not know e) Refuse to answer
4.	<p><i>Compound interest 2</i></p> <p>Suppose you put money in the bank for two years and the bank agrees to add 15 percent per year to your account. Will the bank add more money to your account the second year than it did the first year, or will it add the same amount of money both years?</p>	One of the following options: a) More b) The same c) Do not know d) Refuse to answer
5.	<p><i>Risk diversification</i></p> <p>Suppose you have some money. Is it safer to put your money into one business or investment, or to put your money into multiple businesses or investments?</p>	One of the following options: a) One business or investment b) Multiple businesses or investments c) Do not know d) Refuse to answer
Panel C: 8 Financial literacy assessment questions from OECD/INFE Toolkit (2018) [50]		
1.	<p>Imagine that five <brothers> are given a gift of \$1,000. If the <brothers> have to share the money equally how much does each one gets?</p> <p>* <brothers> could be substituted</p> <p>** the currency could be substituted</p>	Record response [Minimum value=0] or One of the following options: a) Don't know b) Refuse to answer c) Irrelevant answer
2.	<p>Now imagine that the <brothers> have to wait for one year to get their share of the \$1,000 and inflation stays at X percent. In one year's time they will be able to buy?</p> <p>* answer d) can be considered correct but should not be read out/shown</p> <p>** the currency could be substituted</p>	One of the following options: a) More with their share of the money than they could today b) The same amount c) Less than they could buy today d) It depends on the types of things that they want to buy e) Don't know f) Refuse to answer

		g) Irrelevant answer
3.	<p>You lend \$25 to a <friend/acquaintance> one evening and he gives you \$25 back the next day. How much interest has he paid on this loan?</p> <p>* the currency could be substituted</p>	<p>Record response [Minimum value=0]</p> <p>or</p> <p>One of the following options:</p> <p>a) Don't know b) Refuse to answer c) Irrelevant answer</p>
4.	<p>Suppose you put \$100 into a <no fee, tax free> savings account with a guaranteed interest rate of 2% per year. You don't make any further payments into this account, and you don't withdraw any money. How much would be in the account at the end of the first year, once the interest payment is made?</p> <p>* the currency could be substituted</p>	<p>Record response [Minimum value=0]</p> <p>or</p> <p>One of the following options:</p> <p>a) Don't know b) Refuse to answer c) Irrelevant answer</p>
5.	<p>[continued...] and how much would be in the account at the end of five years [add if necessary: remembering there are no fees]? Would it be:</p>	<p>One of the following options:</p> <p>a) More than \$110 b) Exactly \$110 c) Less than \$110 d) It impossible to tell from the information given e) Don't know f) Refuse to answer g) Irrelevant answer</p>
6.	<p>An investment with a high return is likely to be high risk?</p> <p>Alternative: If someone offers you the chance to make a lot of money there is also a chance that you will lose a lot of money.</p>	<p>One of the following options:</p> <p>a) True b) False c) Don't know d) Refuse to answer</p>
7.	<p>High inflation means that the cost of living is increasing rapidly?</p>	<p>One of the following options:</p> <p>a) True b) False c) Don't know d) Refuse to answer</p>
8.	<p>It is usually possible to reduce the risk of investing in the stock market by buying a wide range of stocks and shares?</p> <p>Alternative: It is less likely that you will lose all of your money if you save it in more than one place.</p>	<p>One of the following options:</p> <p>a) True b) False c) Don't know d) Refuse to answer</p>

Panel D: Alternative questions for financial literacy assessment from relevant research

1.	Suppose a 15-year mortgage and a 30-year mortgage have the same Annual Percentage Rate and the same amount borrowed. The total amount repaid will be:	One of the following options: a) Higher for the 15-year mortgage b) Higher for the 30-year mortgage c) The total amount repaid on both mortgages will be the same d) Don't know	[51]
2.	<i>Numeracy [non-amortizing mortgage]</i> Suppose you owe £200,000 on a mortgage with at an Annual Percentage Rate of 5%. If you made annual payments of £10,000 per year how long would it take to repay the whole mortgage?	One of the following options: a) Less than 20 years b) Between 20 and 30 years c) Between 30 and 40 years d) The mortgage would never be repaid e) Don't know	[51]
3.	<i>Numeracy [interest compounding]</i> Cheryl owes £1000 on her bank overdraft and the interest rate she is charged is 15% per year. If she didn't pay anything off, at this interest rate, how much money would she owe on her overdraft after 1 year?	One of the following options: a) £850 b) £1000 c) £1150 d) £1500 e) Do not know	[39]
4.	<i>Numeracy [interest compounding]</i> Sarah owes £1000 on her credit card and the interest rate she is charged is 20% per year compounded annually. If she didn't pay anything off, at this interest rate, how many years would it take for the amount she owes to double?	One of the following options: a) Less than 5 years b) Between 5 and 10 years c) More than 10 years d) Don't know	[39]
5.	<i>Numeracy [interest compounding]</i> David has a credit card debt of £3000 at an Annual Percentage Rate of 12% (or 1% per month). He makes payments of £30 per month and does not gain any charges or additional spending on the card. How long will it take him to pay off this debt?	One of the following options: a) Less than 5 years b) Between 5 and 10 years c) More than 10 years d) None of the above, he will continue to be in debt	[39]

		e) Don't know	
6.	<p><i>Numeracy [interest compounding]</i></p> <p>Suppose you owe £50,000 on a mortgage at an Annual Percentage Rate of 6%. If you didn't make any payments on this mortgage how much would you owe in total after one year?</p>	<p>One of the following options:</p> <p>a) Less than £50,000 b) £50,000 - £54,999 c) £55,000 - £59,999 d) £60,000 - £64,999 e) More than £65,000 f) Don't know</p>	[52] and [51]
7.	<p><i>Numeracy [interest compounding]</i></p> <p>Suppose you owe £100,000 on a mortgage at an Annual Percentage Rate of 5%. If you didn't make any payments on this mortgage how much would you owe in total after five years?</p>	<p>One of the following options:</p> <p>a) Less than £120,000 b) Between £120,000 and £125,000 c) More than £125,000 d) Don't know</p>	[52] and [51]
8.	<p><i>Numeracy [notion of the time value of money]</i></p> <p>You purchase an appliance which costs \$1,000. To pay for this appliance, you are given the following two options: a) Pay 12 monthly installments of \$100 each; b) Borrow at a 20% annual interest rate and pay back \$1,200 a year from now. Which is the more advantageous offer?</p>	<p>One of the following options:</p> <p>a) Option (a) b) Option (b) c) They are the same d) Don't know e) Prefer not to answer</p>	[52]

3.2.1 Resulting Measure of Financial Literacy for EVIDENT

In this section, we propose a framework to measure the level of financial literacy and estimate the behaviour of the people regarding the risks they ought to take in their financial decisions, thus will try to estimate the instrumental variables that lead their actions. The questions of central interest are “Does financial and technological literacy lead individuals to careless or careful financial decisions?” and “Does financially and technologically literate individuals combined with a high sense of overconfidence are prone to risk or do they avoid risk in their decision making?”.

Since there is a lot of discussion about cognitive reflection and decision making [3] [4] [5] it would be interesting to examine how new technologies and the convenience technology offers affect people decisions and strengthen or weaken their behavioural biases. In the 21st century where FinTech first emerged, more and more people gain access to the financial system and started using their smart devices for everyday transactions. Considering the coronavirus pandemic (COVID-19) we would expect that the amount of these people to explode. However, is the usage of technology in our everyday life capable of suppressing people irrational behaviour and leading to more sophisticated decision making or does it lead to the opposite results?

The EVIDENT financial literacy assessment questionnaire-based toolkit consists of 19 items organised into 7 logical phases named Self-assessment, Financial knowledge, Technology knowledge, Self-management,

Present bias, Risk and Overconfidence and 3 categories knowledge and Skills, Attitude and behaviour, and Behavioural Biases. Table 10 presents the questions used in the EVIDENT Financial Literacy toolkit among their available responses, phases, categories and their sources. The correct answers, when applicable, are presented in **bold**.

At the beginning of the questionnaire, phase one, the participant will have to self-evaluate their financial knowledge, thus a question from [6] will provide an indication about the participant’s belief in his own knowledge. Later, this parameter will be used as a proxy to compare the answers provided in this first section with the answers to more objective measures to determine whether people know how much they know. The reason this phase is presented at the beginning is to a) prevent the participants answer the question considering their progress in the rest of the questions since the question is about the “overall financial knowledge” and b) to intrigue the participants to actively participate to the questionnaire, since starting the process with a self-assessment question might be a factor triggering participants willing to pay attention to the whole process.

In the second phase, five questions as proposed by Klapper, Lusardi and van Oudheusden (2015) [7] will be used (section 3.2). The questions measure the four fundamental concepts for financial decision-making: basic numeracy, interest compounding, inflation, and risk diversification. These questions will be used to objectively measure participants financial literacy levels. Similarly, in the next phase, phase three, three questions about technology knowledge will be used to elicit participants’ technological literacy levels. Since more and more people have access to financial technology applications (e.g., online banking, e-shop, investment and trading applications, consulting, etc.) every day we expect that technology knowledge combined with financial knowledge will play a crucial role in people’s decision-making process.

The next phase, phase four, consists of four questions related to self-management. With these questions, we will be able to gain information about participants attitudes and behaviours and have an overview of their financial background. We will be able to identify behaviours related to long term goals and learn if there are actively involved in trading activity.

The next three phases are devoted to behavioural biases. More specifically, phase five includes questions related to present bias (section 3.1.8) while in phase six, three questions about risk aversion and risk preference (section 3.1.5) will be used to see whether the participant is willing to take risks. Finally, phase seven considers the factor of overconfidence (section 3.1.2) as an explanatory parameter of participant behaviour thus a question based on J. Oechssler, A. Roider, and P. W. Schmitz (2009) is used.

Table 10: EVIDENT Form Measure of Financial Literacy

Category	Source	Questions	Response Options
First Phase: Self-assessment			
Knowledge and Skills	[52]	How would you assess your overall financial knowledge? Please use a scale of 1 to 7, where: 1 means very low and 7 means very high.	Scale from 1 to 7 or one of the following options: a) Don’t know b) Refuse to answer

Second Phase: Financial knowledge			
Knowledge and Skills	[48]	<p><i>Numeracy [interest compounding]</i></p> <p>Suppose you need to borrow 100 US dollars. Which is the lower amount to pay back: 105 US dollars or 100 US dollars plus three percent?</p>	<p>One of the following options:</p> <p>a) 105 US dollars b) 100 US dollars plus three percent c) Do not know d) Refuse to answer</p>
	[48]	<p><i>Inflation</i></p> <p>Suppose over the next 10 years the prices of the things you buy double. If your income also doubles, will you be able to buy less than you can buy today, the same as you can buy today, or more than you can buy today?</p>	<p>One of the following options:</p> <p>a) Less b) The same c) More d) Do not know e) Refuse to answer</p>
	[48]	<p><i>Compound interest 1</i></p> <p>Suppose you had 100 US dollars in a savings account and the bank adds 10 percent per year to the account. How much money would you have in the account after five years if you did not remove any money from the account?</p>	<p>One of the following options:</p> <p>a) More than 150 dollars b) Exactly 150 dollars c) Less than 150 dollars d) Do not know e) Refuse to answer</p>
	[48]	<p><i>Compound interest 2</i></p> <p>Suppose you put money in the bank for two years and the bank agrees to add 15 percent per year to your account. Will the bank add more money to your account the second year than it did the first year, or will it add the same amount of money both years?</p>	<p>One of the following options:</p> <p>a) More b) The same c) Do not know d) Refuse to answer</p>
	[48]	<p><i>Risk diversification</i></p> <p>Suppose you have some money. Is it safer to put your money into one business or investment, or to put your money into multiple businesses or investments?</p>	<p>One of the following options:</p> <p>a) One business or investment b) Multiple businesses or investments c) Do not know d) Refuse to answer</p>
Third Phase: Technology knowledge			

<p>Attitude and Behaviour</p>	<p>OECD/INF E Toolkit (2018) [50]</p>	<p>I use my <mobile phone> to make or receive payments.</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know b) Refuse to answer</p>
<p>Knowledge and Skills</p>	<p>-</p>	<p>Are you aware of the blockchain technology?</p>	<p>One of the following options:</p> <p>a) I know everything about the blockchain technology b) I am aware of the main concept c) Do not know d) Refuse to answer</p>
<p>Attitude and Behaviour</p>	<p>OECD/INF E Toolkit (2018) [50]</p>	<p>I believe that it is a good time for people to invest in crypto-assets or initial coin offering (ICOs).</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know b) Refuse to answer</p>
<p>Fourth Phase: Self-management</p>			
<p>Attitude and Behaviour</p>	<p>OECD/INF E Toolkit (2018) [50]</p>	<p>I keep a close personal watch on my financial affairs.</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know b) Refuse to answer</p>
	<p>OECD/INF E Toolkit (2018) [50]</p>	<p>I set long term financial goals and strive to achieve them.</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know b) Refuse to answer</p>
	<p>OECD/INF E Toolkit (2018) [50]</p>	<p>I have too much debt right now.</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know b) Refuse to answer</p>

	[6]	Are you actively involved in trade activity?	One of the following options: a) Strongly disagree b) Disagree c) Somewhat agree d) Agree e) Strongly agree
Fifth Phase: Present bias			
Behavioural Biases	OECD/INF E Toolkit (2018) [50]	I find it more satisfying to spend money than to save it for the long term. Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.	Scale from 1 to 5 or one of the following options: a) Don't know b) Refuse to answer
	[40]	I intend to live in the present more and do not consider the future. Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.	Scale from 1 to 5 or one of the following options: a) Don't know b) Refuse to answer
Sixth Phase: Risk			
Behavioural Biases	[22]	How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please use a scale of 1 to 5, where: 1 means that you are "unwilling to take risks", and 5 means that you are "fully prepared to take risk"	Scale from 1 to 5 or one of the following options: a) Don't know b) Refuse to answer
	OECD/INF E Toolkit (2018) [50]	I am prepared to risk some of my own money when saving or making an investment. Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.	Scale from 1 to 5 or one of the following options: a) Don't know b) Refuse to answer

	[6]	<p>Do you make investments to make money quickly?</p> <p>Please use a scale of 1 to 5, where: 1 means that you completely agree with the statement and 5 means that you completely disagree with the statement.</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know</p> <p>b) Refuse to answer</p>
Seventh Phase: Overconfidence			
Behavioural Biases	Based on [5]	<p>What do you think, how many of the Financial Knowledge questions did you answer correctly?</p>	<p>Scale from 1 to 5</p> <p>or</p> <p>one of the following options:</p> <p>a) Don't know</p> <p>b) Refuse to answer</p>

4. The concept of environmental literacy and its assessment tools

4.1 Overview of Environmental Literacy

The impact of human behaviour on both local and global environments is being increasingly brought to the attention of the general public. The large and varied environmental threats including pollution of air and water, global warming, biodiversity depletion, soil infertility, deforestation, waste and reduced natural resources, all pose immediate and severe challenges [53]. These environmental challenges are difficult and complex, and are impacted by numerous social, political and economic factors [54]. As such, significant skills are needed to understand and critically analyse these topics [55]. In the context of these challenges, there is a need for aware, articulated and active citizens, willing to engage in action [54], [56] and aware of social, political and economic factors as they pertain to environmental topics [57]. To support, this additional analysis of how individuals can be supported to enhance their environmental knowledge is needed.

Environmental literacy has been highlighted as a means through which individuals may be facilitated to engage in greater levels of pro-environmental behaviour and increase environmental awareness. Environmental literacy is an individual's awareness of how human behaviour impacts the environment and actions required to address these impacts [58]. It is a measure of a person's knowledge about the interactions of humans and their environments, environmental issues, and the various connections in ecological systems [59]. Put simply, it is a person who "knows enough to care, cares enough to learn more, and learns more to act" [60]. More recently the concept of environmental literacy has been expanded to consider the increasingly connected global environment [9]. Rather than an individual pursuit, environmental literacy is proposed to consist of active, engaged citizens and leaders, and promotion of environmental-focused dialogue across public and social spheres. Recent studies have demonstrated major shortcomings in the public's understanding and awareness of environmental issues [59]. The National Report Card on Environmental Attitudes, Knowledge and Behaviour (NEETF)[62], [10] found 66% of American adults failed to correctly answer simple environmental questions. Interestingly, 70% felt they had sufficient knowledge, suggesting a discrepancy between perceived and actual environmental knowledge. Environmental literacy levels have remained stable [62], [63], though the gap between those with high and lower environmental literacy is growing [64]. Low environmental literacy in turn has been found to contribute to deficits in energy policy [65], with shortcomings in environmental literacy levels impacting the quality of policy proposals [66], [67]. As such, a means to enhance environmental literacy skills while emphasising global citizenship is needed [68]. To address this, analysis of environmental literacy is needed to determine how best to support individuals to engage more positively with the natural environment.

To date, environmental literacy interventions have primarily been directed towards educational settings and school age groups [56]. The highly complex nature of environmental challenges positions formal education settings as an ideal avenue through which skill acquisition can be attained [69], [70]. In addition to increasing environmental science knowledge, functional, cultural, and critical literacy skills are also addressed [71]. Through supporting environmental knowledge acquisition, formal education facilitates the processing and analysis of environmental information [72]. While research has examined the role of formal education systems in supporting environmental literacy development, limited analysis in adult non-education populations has occurred [60].

4.1.1 Defining Environmental Literacy

Environmental literacy is the ability to examine the state of the natural environment and to take action to maintain or restore the health of that environment [56]. It includes both awareness of the environment, and the skills and motivation to support it [73]. In this context, literacy is used to surmise the integration of thinking, valuing and acting as it pertains to the environment, embedded within a wider social context. While this broad definition is well accepted [74], some variance in the specific content of environmental literacy definitions has been noted. A universally agreed definition has yet to be determined [75]. The term environmental literacy itself has become overused to the point that it has limited accepted meaning [56], and is used interchangeably with other terms to encompass environmental education as a whole. Further the interchangeable use of different terms such as ecoliteracy, ecological literacy and environmental literacy has diluted meaning [74]. Key definitions of environmental literacy and their key components are presented in Table 11 below. In order to examine the role of environmental literacy in supporting pro-environmental behaviour, a definition of environmental literacy must first be determined. This section will provide insight into environmental literacy, how it is measured and how it impacts pro-environmental behaviour and attitude.

Environmental literacy was first described as an individual's knowledge and awareness of the impact of their behaviour on the environment [76]. As such, it can be considered the inter-relationship between people and the natural environment [77]. Arising from this definition four primary aspects of environmental literacy were posited [56]. The first of these was the interrelationship between nature and social systems, highlighting the interconnectedness of humans and their environments. A second aspect was unity across people and nature, which emphasises the impact humans have on their environments. Thirdly, the use of technology as a means to mitigate environmental impacts was noted. The final aspect is learning across the lifespan, which emphasises the need for ongoing learning and development of skills as a continuous process. As such, literacy draws upon an individual's environmental attitude, knowledge, values, actions, personal interest and responsibility. This initial definition is echoed in McBeth et al [78] who note four components of environmental literacy, namely ecological knowledge (understanding of ecological issues), environmental affect (verbal commitment to environmental action), cognitive skills (identification of environmental issues and resultant actions) and behavioural commitment (willingness to engage in environmental behaviours). Similarly, Coyle [79] identified three levels of environmental literacy. These are awareness (i.e. familiarity with the environment), personal conduct knowledge (i.e. willingness to take action and an awareness of the impact of own behaviour), and true literacy (understanding environmental issues and having the skills and motivation to examine and act on these issues). As such, while no singular agreed definition exists, strong commonalities across definitions have been noted.

The development of environmental literacy is underpinned by four key documents [60]. These are the Belgrade Charter [80], the Tbilisi Declaration [81], the International Strategy for Action of Environmental Education and Training for the 1990s [82], and Agenda 21 [83]. The need to develop environmental literacy across the population was first raised within the Belgrade Charter [80]. This document noted the need for education in response to environmental degradation and the impact of human behaviour on the environment. Following this the need for environmental literacy to be considered a fundamental goal of education was raised within the UNESCO-UNEP [84] publication 'Environmental Literacy for All'. The need for an international framework was first raised in 1972 at the UN conference on Human Environment in Stockholm. Following this an Intergovernmental Conference on environmental education occurred, with the resultant aims and goals of this conference known as the Tbilisi Declaration [81]. The Tbilisi Declaration is particularly important in the development of environmental literacy and continues to impact how it is

approached. From this, a key model of environmental literacy arose, the Awareness, Knowledge, Attitude, Skills, Action (AKASA) model. AKASA consists of five categories of objectives. The first of these is awareness, or an understanding and sensitivity to the environment and its concerns. Secondly, knowledge pertains to a basic understanding of how the environment works. Thirdly, attitudes describe the motivations and values of individuals in relation to the environment. Fourthly, skills consist of the tools to identify and solve environmental problems as they emerge. Finally, action includes behaviours taken to support the reduction of environmental problems. Each step in the model is independent, though progress in one step may support or inform the others [64]. Environmental literacy within this model is considered a hierarchical process and determines how individuals interact with their environments. This model serves as a key guiding principle in environmental education and underlines environmental literacy research.

Arising from AKASA two primary approaches to environmental literacy were developed. Both of these address three of the thematic emphases of environmental education namely the natural world, environmental problems, and sustainable solutions [85]. The basis of the first approach derived from a review of environmental literacy definitions and theoretical frameworks [86]. Results suggest seven key components, namely affect, ecological knowledge, socio-political knowledge, environmental issue awareness, cognitive skills and pro-environmental behaviour. The findings of this review formed the basis of the NAAEEs Guidelines for Learning [73], which in turn are used to determine how environmental education is addressed in practice. The NAAEE more recently list four components of environmental literacy, inclusive of contexts (i.e. awareness of local and global environment), competencies (i.e. can identify environmental issues), personal conduct (i.e. awareness of own action and willingness to act) and true literacy (i.e. understanding, skill and motivation regarding environmental issues) [87]. The second approach devised a framework to develop tools to determine the environmental literacy of students and teachers [88]. While no single agreed upon definition of environmental literacy has been developed, significant commonalities have been noted. Commonalities across definitions of environmental literacy as they pertain to the ASAKA model can be observed in Table 11 below. While most definitions are consistent with the ASAKA model, an absence of behavioural considerations can be noted for some [89] and an absence of attitudinal variables noted for others [90].

The notion of environmental literacy as a continuum, rather than a discrete entity, has been raised. One such approach noted three levels of environmental literacy [56]. These are nominal literacy wherein an individual can observe and label environmental issues, functional literacy in which an individual has a broader knowledge base and can engage in action in at least one environmental area, and finally, operational literacy wherein the knowledge base is further expanded, and the individual can act in multiple areas. This continuum emphasises the differing levels of aptitude across multiple domains, from knowledge to action, and emphasises the need for environmental knowledge and action across broader environmental concerns. Such an approach allows the environmental literacy skills of a wide variety of individuals to be appropriately captured and goals determined based on current levels. Three levels of environmental literacy are also highlighted by Harvey [91]. These are 1) environmentally literate, 2) environmentally competent and 3) environmentally dedicated. While those who are environmentally literate may have strong environmental knowledge, those who are environmentally competent enhance this knowledge with behavioural intent. Those who are environmentally dedicated differ again in that environmental actions are valued and personal responsibility considered. It is clear from both approaches that environmental literacy consists of multiple stages comprising of awareness, concern, understanding and action [56]. As such, environmental literacy should be considered a lifelong pursuit, with a need to continuously develop skills [61]. This also suggests a need to determine levels of environmental literacy across the population, rather than its presence or absence.

More recently the importance of cognitive skills and critical analysis within environmental literacy has been highlighted. Cognitive skills appear particularly necessary for environmental literacy, with a need to have a basic understanding of ecological processes, the impact of human systems on these ecological processes and strategies which can be used to address these effects [56], [75], [92]. Critical analysis of environmental challenges to determine actions available to remediate these challenges have been highlighted [93]. While past definitions have highlighted the need for knowledge and action planning this emphasis on critical analysis requires additional consideration.

A number of key points can be gathered from this for use within the EVIDENT project. While a commonly agreed upon definition of environmental literacy has yet to be determined, high levels of consistency across definitions have been noted. One approach to defining environmental literacy which appears key is the AKASA model which underpins many other definitions of environmental literacy. The importance of incorporating knowledge, attitude, awareness, behaviour and action when defining environmental literacy is clear, with an emerging role of values and critical analysis also noted. The nature of environmental literacy as a continuum along which each of these aspects of environmental literacy develop is also posited. As such, EVIDENT should seek to ensure that any measure of environmental literacy employed includes the components of the AKASA model with consideration to the role of critical analysis skills.

Table 11: Common Definitions of Environmental Literacy and their Inclusion of ASAKA Components

Reference	Key Components	Aspects of ASAKA included				
		Awareness	Knowledge	Attitude	Skills	Action
Tbilisi Declaration [81]	AKASA model 1) Awareness 2) Knowledge 3) Attitude 4) Skills 5) Action	x	x	x	x	x
Harvey [91]	Three levels of literacy 1) Environmentally literate, 2) Environmentally competent 3) Environmentally dedicated	X	x	x	x	x
Hungerford et al [94]	Four goal levels of environmental literacy 1) Ecological knowledge 2) Conceptual awareness of behavioural impacts on the environment 3) Skill in issue identification 4) Action skills	x	X		x	X
Ballard & Pandya [89]	Three key systems for environmental literacy 1) Natural Systems 2) Resources 3) Human Systems	x	x			
Marcinkowski [95]	Nine items comprising of environmental literacy 1) Awareness and sensitivity toward the environment 2) Respect and concern for the natural environment 3) Understanding of natural and social systems 4) Understanding of environmental problems, on a local and global level. 5) Ability to analyse and critically evaluate environmental concerns 6) Personal responsibility	x	x	x	x	x

	7) Ability to act to address environmental concerns 8) Skills to develop an action plan 9) Active involvement in resolving environmental concerns					
Roth [56]	Four Factors 1) The interrelationship between nature and social systems 2) Unity across people and nature 3) Use of technology 4) Learning across the lifespan	x	x			
Simmons et al., [86]	6 key components 1) Affect 2) Ecological knowledge 3) Socio-political knowledge 4) Environmental awareness 5) Cognitive skills 6) Pro-environmental behaviour	x	x	x	x	xx
Elder [64]	Includes 1) Awareness 2) Knowledge 3) Skills 4) Attitudes	x	x	x	x	
NSTA [96]	Nine declarations for environmental literacy 1) Observation, investigation, experimentation, and innovation. 2) Scientific literacy 3) Knowledge of environmental concerns 4) Critical thinking 5) Awareness of global issues and solutions/ actions. 6) Consideration of environmental, economic, and social perspectives 7) Use of technology 8) Formal and informal learning	x	x	x		

	9) Enhanced through exchange between formal and informal settings.					
Coyle [79]	Three factors 1) Awareness (familiarity with the environment) 2) Personal conduct knowledge (willingness to act and awareness own behavioural impact) 3) True literacy (understanding environmental issues and having the skills and motivation to act)	x	x	x		
McBeth et al., [78]	Four factors 1) Ecological knowledge 2) Environmental affect (verbal commitment) 3) Cognitive skills (identification of issues and actions) 4) Behavioural commitment	x	x	x	x	x
Nichols [90]	'Essential Ecoliteracy' consisting of 4 domains; 1) Concepts 2) Sense of place 3) Respect for others 4) Competencies which align with knowledge, affect, morals and skills	x	x		x	
McBride [97]	6 key dimensions 1) Cycles and webs (movement of matter, food webs) 2) Ecosystem services (benefits humans derive from nature) 3) Negative human aspects (harm caused to the environment) 4) Critical thinking 5) Ecological science 6) Biogeography (change in ecosystems over time)	x	x	X		
Hollweg et al. [54]	4 components 1) Knowledge 2) Dispositions		x	x	x	x

	<ul style="list-style-type: none"> 3) Competencies 4) Pro-environmental behaviour 					
NAAEE [87]	<p>Consists of</p> <ul style="list-style-type: none"> 1) Contexts (i.e. physical environmental awareness, local area) 2) Competencies (i.e. can identify and analyse environmental concerns) 3) Environmental knowledge (knowledge of the environmental context and ability to determine ways forward) 4) Dispositions toward the environment (i.e. behavioural intention). 	x	x	x	x	
Shri & Tiwari [65]	<ul style="list-style-type: none"> 1) Awareness of the local environment 2) Awareness and knowledge about environmental problems 3) Attitudes towards environmental protection 	x		x		

4.2 The impact of environmental literacy on attitudes and decision-making

While the importance of developing environmental literacy has been posited, the relationship between it and pro-environmental behaviour is still to be fully determined [75]. While differing perspectives on environmental literacy and human-environmental relations have been found (e.g., [98]–[100]), the link between behaviour, attitude and environmental knowledge remains unknown. While research suggests that pro-environmental behaviour reflects an individual's environmental literacy, increased environmental literacy does not necessarily result in increased pro-environmental behaviour [56], [88]. As such, environmental awareness does not always lead to positive behaviour change [101]. Pro-environmental behaviour is a repertoire of learned behaviours, embedded within a larger social context [102] and as such the development and use of this repertoire is impacted by environmental contingencies. Further analysis into the specific factors which mediate this behaviour-environmental literacy relation requires additional analysis. Three key factors which have been posited to mediate the relationship between environmental literacy and pro-environmental behaviour are attitude, cognitive skills and community. The impact of each of these factors will be discussed in turn.

4.2.1 Impact of Attitude on Environmental Literacy and Behaviour

Environmental literacy has a limited effect on behaviour in natural environments [101], [103]. As such, increasing environmental literacy alone may not be sufficient to establish behaviour change [103]. Rather, the impact of environmental literacy on attitude [104] and demographic factors [105] should be considered to determine how best to establish lasting behaviour change. A key area of debate is the relationship between environmental knowledge, attitude and behaviour [106]. Research suggests that environmental literacy may mediate the relationship between attitude and behaviour [107]. The Environmental Literacy Components Model sought to explain how attitude, responsibility, knowledge and concern interact [108]. Results suggest environmental knowledge as a key predictor of environmental attitude. Responsibility and concern were also found to have an impact. As such, through the acquisition of environmental literacy skills, those with positive environmental attitudes may be supported to engage in greater levels of pro-environmental behaviour. Researchers have also sought to examine the sub-dimensions of environmental literacy using structural equation modelling [109]. Positive relations between knowledge, attitude and environmental behaviours were noted. Results suggested that greater environmental knowledge was positively associated with attitude. In addition, those with more positive attitudes were more willing to learn about the environment. The model of responsible environmental behaviour notes the impact of attitudes, locus of control and personal responsibility as personality factors, which in addition to action skills, knowledge of action and knowledge of issues contributes to an intention to act [92]. Intention to act and situational factors then interact to result in responsible environmental behaviour. This suggests environmental literacy may support environmental behaviour through positively impacting environmental attitudes.

However, as environmental attitudes are difficult to measure their impact on pro-environmental behaviour remains the focus of intense discussion within the literature [110]. Recent research has highlighted the impact of affect, rather than attitude, on behaviour [111]. The role of affect on pro-environmental behaviour has been examined from a number of lenses, with emotional connection [112], willingness [78], self-efficacy [54] and hope [111] all demonstrating impacts. Analysis of how

environmental literacy may better consider affect is needed. Additionally, consideration as to the relationship between affect, environmental literacy and behaviour is also needed.

Research has also considered the importance of values in supporting environmental literacy and pro-environmental behaviour. A recent study sought to determine the relationship between knowledge, values and behaviour [113]. Results suggested a linear relationship between knowledge and values, values and behaviour, and knowledge and behaviour. Additionally, the behaviour was found to be more closely linked to values in comparison to knowledge. This suggests a key role of environmental literacy in supporting the development of environmental values, which in turn impact behaviour. This is in line with past research which suggests knowledge to be the basis of values [114]. Values may also positively impact environmental behaviour by reducing denial. A recent study sought to examine the psychological barriers which may impact energy conservation behaviour [115]. Results found that denial reduced energy conservation behaviour by reducing the moral impetus. Environmental knowledge mitigated this effect, resulting in increased energy conservation behaviour, suggesting a protective effect. However, while values appear to positively impact environmental behaviour a challenge remains in addressing value-action gaps [116], to ensure individuals act in line with increased environmental knowledge. These results highlight the need for personal values and stewardship to be developed as part of environmental literacy to support effective action.

4.2.2 Impact of cognitive skills on environmental literacy and behaviour

The impact of cognitive skills on both environmental literacy and behaviour has also been considered. Research examining the impacts of environmental knowledge acquisition on pro-environmental behaviour is mixed, with some noting positive effects [102] and some noting an absence of effects [117]. This suggests a non-linear relationship between cognitive skills and behaviour requiring analysis [102]. Hungerford & Volk's [117] traditional assumption of environmental behaviour found that environmental knowledge leads to increased environmental awareness which in turn leads to pro-environmental behaviour. This model highlights both major and minor factors which may impact environmental behaviour. These include entry level variables (i.e. environmental sensitivity, ecological knowledge), ownership variables (i.e. in-depth knowledge on environmental concerns, understanding of consequences of behaviour, personal commitment), empowerment variables (i.e. locus of control, skill in using environmental actions) and citizenship behaviour. This suggests the impact of cognitive skills on behaviour through impacting environmental knowledge.

The impacts of different forms of knowledge have also been noted. For example, the difference between objective and subjective knowledge is of note [115]. Individuals tend to underestimate their objective financial and energy knowledge [118]. This suggests a need to support accurate judgements of knowledge to support behaviour change. Three forms of knowledge have been noted which may impact pro-environmental behaviour [119]. These are factual, action-specific and effectiveness knowledge. Analysis of this model suggests it may be an effective means to explore environmental knowledge types and their impact on behaviour [114]. Results suggest that factual knowledge alone may not be sufficient to influence behaviour (e.g.[120]). However, action (e.g.[53]) and effectiveness knowledge do impact behaviour [121]. This suggests an important role of supporting competence in environmental action and effectiveness rather than knowledge alone to support pro-environmental behaviour. As such, there is a need for environmental literacy to incorporate action and effectiveness specific knowledge targets to support effective environmental impacts.

A further cognitive skill that has been emphasised is critical analysis. Individuals who have stronger critical thinking skills are more able to process environmental information and determine actions which can be undertaken to meet environmental needs [122]. Research suggests that for environmental change to occur there is a need to support individuals to develop analytic and reflective skills to teach them to strive for better as it pertains to the environment [123]. This need for critical analysis skills has been termed critical ecoliteracy [124] and can be considered under an environmental literacy umbrella. Critical analysis skills may be predicted by knowledge and values, and may in turn predict behaviour [111]. However the link between critical analysis skills and environmental behaviour requires additional analysis as clear links are yet to be established. Recent research noted that while positive interaction between critical thinking skills and environmental literacy was found, these effects did not reach statistical significance [125]. This suggests a need for additional analysis of how critical analysis skills may be impacted by environmental literacy, and in turn impact behaviour.

4.2.3 Role of community factors on environmental literacy and behaviour

Further factors that may impact the effects of environmental literacy on behaviour are community level factors. The mitigating role of community on pro-environmental behaviour and environmental literacy has been highlighted. Creating an environmentally literate society requires community action and co-operation. Educational, social and cultural factors contribute to environmental knowledge [126]. While past research has focused on 'I' statements in environmental literacy education, a need to emphasise the importance of collective action has been found [127]. Positive effects for the use of implementation science and local wisdom in developing environmental literacy for students has been noted [125]. It is clear that social factors impact environmental literacy, consideration to the role played by local wisdom is needed. Behaviour change requires a larger cultural effort with a need for regulatory, policy and community supports [116]. Environmental literacy may provide both a foundation for increased environmental awareness and also contribute to more effective behaviour choices facilitating more sustainable communities [65].

Urban versus rural habituation also appears to mitigate the impacts of environmental literacy on pro-environmental behaviour with those who live in rural environments having increased awareness of environmental issues [128]. An examination of the impact of economic development on environmental literacy found high environmental literacy associated with more frequent visits to rural areas, residing in rural areas, knowledge acquisition from peers and family [129]. Those who depended on the environment for their livelihoods also had greater environmental literacy. Oral knowledge transfer of knowledge was found to be key to the acquisition and maintenance of environmental literacy in communities. This suggests a key role played by communities in supporting the development of environmental literacy and lasting behaviour change.

While research suggests an impact of community level factors on environmental literacy and behaviour, few studies have noted the importance of community specific social, cultural or political factors. While many factors have been highlighted as contributing to environmental literacy decline including urbanisation and globalisation [129], these factors are broad and the specific means by which they impact environmental literacy is undetermined. Additionally, an absence of analysis of the impacts of environmental literacy on environmental management behaviours for those who are of low socio-economic status has been noted [130]. This suggests a need for additional analysis of the impacts of community level factors on environmental literacy and resulting behaviour.

4.3 Empirically assessing the environmental literacy level

As environmental literacy is a spectrum from limited knowledge to strong understanding, there is a need to determine individual environmental literacy levels. While environmental literacy levels can be determined through observable behaviours [56], this is often impractical to examine on a large scale. Instead, several standardised measures of environmental literacy have been developed to determine the environmental literacy levels of the population at large. However, to date, there is no one standard measure of environmental literacy [75]. Rather, a number of key measures have been developed, as outlined in Table 12 below.

Five primary means of measuring environmental literacy have been noted in the literature. The first of these is the New Environmental Paradigm Scale (NEP) [131], [132] which considers both ethics and values in human-environmental relations. A second primary tool used to measure environmental literacy is the First Pennsylvania Environmental Readiness for the 21st Century Survey Report [133]. This tool was used in one of the first studies examining large-scale environmental literacy and includes measures of knowledge, attitude and behaviour toward the environment. A third primary measure is the Needs Assessment for Environmental Education [134], which was developed by the State of Florida with the purpose of assisting the Advisory Council on Environmental Education (ACEE) guide environmental education initiatives. A fourth commonly used tool is The Middle School Environmental Literacy Survey [135]. This includes measures of environmental literacy including ecological knowledge, verbal and actual commitment, pro-environmental behaviour, sensitivity to the environment, skills in environmental issue identification and action planning. It in turn measures knowledge, affect, cognitive skills and behaviour. The final, and most common, means of measuring environmental literacy is the AKASA model, which arose from the Tbilisi Declaration [81] and is described in section 4.2. This model consists of five components, namely awareness, knowledge, attitude, skills and action to determine overall environmental literacy. Most past environmental literacy literature is based on AKASA components, considering environmental literacy as a hierarchical process which determines how individuals act and engage in their environments. However, while the AKASA is a good starting place, more consideration is needed into how environmental literacy is measured [60]. It is of note that each of these measures was developed primarily for use in American educational settings. This poses a limitation as expected environmental literacy levels for the general population may differ from educational contexts. In addition, as each of the measures was developed in similar locations, cultural factors relevant in other settings may not have been considered. As such generalisation across locations may be impacted. This suggests a need for non-educational measures developed in novel locations.

A number of more recent methods to measure environmental literacy have also been noted across the literature, the majority of which are based upon or add to the five measures above. A fulsome description of common tools is presented in Table 12. Leeming et al [110] developed a scale designed to measure the environmental attitude and knowledge of school children in America, and is considered a good measure of global environmental literacy. The longitudinal study of American youth has also been amended and used as a measure of environmental literacy [136]. More recently, efforts to measure environmental literacy using instruments adapted to match local concerns have occurred. One such example is O'Brien [60] who examined cultural and globally relevant environmental literacy concerns and from this developed a survey which considered environmental literacy from the perspective of these concerns. Key local concerns included climate change, population growth, pollution, biodiversity and environmental education. Key global concerns included agriculture, water quality, habitat loss, urban expansion and land use. The researchers then used adapted versions of the NEETF alongside newly composed questions to examine environmental literacy with success. Similarly, Teksoz et al., [108] adapted an environmental

literacy survey [137] inclusive of questions on knowledge, attitudes, responsibility and concern to examine environmental literacy. Good reliability for the measure was found [79]. This suggests the need for adaptation of environmental literacy measures to better reflect the context in which they are being used.

A key limitation of past measures of environmental literacy is their length, with surveys often containing many questions and taking ample time to complete. However, longer measures risk attrition or incomplete responses should the response burden become too great. As such, shorter instruments are needed to facilitate greater completion rates and less attrition [138]. Recent research has responded to this need for short environmental literacy measures with the development of the Environmental Literacy Instrument for Adolescents (ELI-A) [111]. This is a short (5-10 minute) survey which includes measures of ecological knowledge, hope, cognitive skills and behaviour. This measure is based on the Tbilisi declaration definition of environmental literacy [84] and is consistent with the US National Environmental Education Act of 1990. As such it includes measures aimed at targeting environmental awareness and sensitivity, knowledge and understanding, attitudes, skills, and participation [139].

A number of key recommendations for EVIDENT can be derived from past measures of environmental literacy. While no standard measure of environmental literacy has been noted, five key measures have been commonly employed across the literature. One such measure, based on the AKASA model appears most popular and should be considered within EVIDENT. However, these commonly used tools have primarily been used in North American education contexts which may pose a limitation. To mitigate against this, adaption of the measure to better reflect the context of the EVIDENT study should be considered, as has been successfully conducted in similar past research. In addition, past research highlights the importance of low response effort for participants when examining environmental literacy to reduce attrition. As such, measures of environmental literacy within the EVIDENT project should be as short as practicable. In summary, a need for a short, context-specific measure of environmental literacy which is based upon the AKASA model, or a similar highly acceptable model, is needed to best examine environmental literacy within EVIDENT.

Table 12: Key Measures of Environmental Literacy

Reference	Tool	Aim/Purpose
Szczytko et al., [111]	Environmental Literacy Instrument for Adolescents	Short environmental literacy measure
Kaplowitz & Levine [137]	Environmental Literacy survey	Includes questions on knowledge, attitudes, responsibility and concern
Wilke [88]	Middle school environmental literacy instrument	Multiple-choice test designed to measure awareness of environmental issues and basic ecological knowledge
Gambro and Switzky, [136]	National survey of high school students	Multiple-choice test of seven items from the Longitudinal Study of American Youth
Hungerford, McBeth & Bluhm, [135]	Middle School Environmental Literacy Survey	Includes demographic items and measures of environmental literacy including ecological knowledge, verbal and actual commitment, pro-environmental behaviour, sensitivity to the environment, skills in environmental issue identification and action, and action planning.

Leeming et al [110]	Environmental Attention scale	Measures environmental attitude and knowledge of school children in America.
Dunlap & Van Liere [131]	New Environmental Paradigm Scale (NEP)	Seeks to determine environmental attitudes and considers ethics and values.
O'Brien [60]	Environmental Literacy Survey	Individualised survey to match local and global needs. Includes sections on attitude, awareness and knowledge.
NEETF & Roper [62]	NEETF/Roper Survey	Examines public understanding of environmental issues and preparedness to act in support of the environment
Bethlendi and Pora [9]	Environmental literacy Survey	Examined environment consciousness, green attitude, financial knowledge, financial attitude, demand for green financial products and price sensitivity.
Bogan & Kromrey, [140]	Florida Environmental Literacy Survey of high school students	Five subtests measuring knowledge of ecological principles, attitude, behaviours, active environmental behaviours and political action
PCEE [133]	The First Pennsylvania Environmental Readiness for the 21st Century Survey Report	Consists of four sections, namely, environmental literacy, attitudes, behaviours and environmental education.
NAAEE framework [87]	NAAEE framework	Consists of four components. These are contexts (awareness of environmental concerns in local, regional, global environments), competencies (ability to examine environmental issues and solutions), environmental knowledge and disposition (locus of control, attitude, sensitivity etc.).

4.3.1 Resulting Measure of Environmental Literacy for EVIDENT

To address the limitations of past measures of environmental literacy, an adapted 50-item measure was developed for use within the EVIDENT project. Consistent with recommendations arising from past literature, the AKASA model was used as the basis of this measure. As such, individual sections targeting awareness, knowledge, attitude, skill and action based on past measures of environmental literacy were included. All individual questions included in the EVIDENT environmental literacy survey are presented in Table 13 below. This measure specifically sought to address the limitations of past measures, including the omission of aspects of environmental literacy (specifically values and critical analysis skills) and generalisation concerns. As most past measures of environmental literacy were developed for North American contexts and education settings included questions were amended to better fit the EVIDENT context. To address this, the wording of questions was amended and some questions removed, to better reflect the concerns of individuals based in Europe.

A number of past measures were used within the current survey. To measure awareness, the attitude and disposition subsection of the National Environmental Literacy/Awareness Survey was used [141]. This measure includes five questions responded to using a five-point likert scale from one (strongly disagree) to five (strongly agree). Knowledge was measured using the NEETF/Roper Survey, which included eleven items with individual response options presented for each question [62]. This survey was adapted for a European sample by removing and re-wording individual questions. In response to the literature, three aspects of attitude were included within the current environmental literacy survey. These are behavioural intention, values and general attitude towards the environment. Behavioural intention is measured using two questions deriving from Wang et al., [142] which seek to determine the individuals willingness to act in support of the environment. Environmental values are determined using the biosphere section of the Environmental Portrait Value Questionnaire (E-PVQ; [143]). This includes four questions, responded to using a seven point Likert scale from one (totally not me) to seven (totally me) and examines self-reported values towards the environment. General environmental attitude is measured using the New Environmental Paradigm Scale (NEP, [131]). This consists of fifteen items responded to using a five-point Likert scale from one (strongly disagree) to five (strongly agree). To determine the skill of respondents as it pertains to environmental literacy, both action planning and critical analysis questions were included. To examine action planning skills six questions were derived from the cognitive skill action planning subsection of Liang et al [144]. Each of these was responded to using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). To examine critical analysis skills an adapted version of the Defining Issues Test ([145] adapted by [111]) was used. For this, participants are presented with an environmental scenario and asked to rank the appropriateness of five responses. Finally, action was measured using the action subscale of Szczytko et al [111]. Within this section, participants were presented with six actions and asked how often they completed them using a four-point Likert scale from zero (never) to three (all of the time).

Table 13: EVIDENT Long-Form Measure of Environmental Literacy

Aspect of Environmental Literacy	Measure Employed	Questions	Response Options	
Attitude	Willingness/Behavioural Intention [142]	Do you think there is room for you to reduce your monthly electricity consumption?	Basically impossible. Can be reduced a bit. Can be reduced a lot.	
		If there is a power-saving measure that can help you reduce your electricity bills, but this measure may change your lifestyle habits. Do you think you might stick to it?	Basically impossible. Can stick for a while. Can stick.	
	E-PVQ -Biosphere section amended [143]	Please read each description carefully and indicate how much this is like you:		
		It is important to prevent environmental pollution.	1 = Totally not like you 2 = Not like you 3 = Somewhat not like you 4 = Neutral 5 = Somewhat like you 6 = Like you 7 = Totally like you	
		It is important to protect the environment.		
		It is important to respect nature		
	It is important to be in unity with nature.			
	NEPS [131]	We are approaching the limit of the number of people the Earth can support.	1 = Strongly disagree 2 = Disagree 3 = Neither 4 = Agree 5 = Strongly agree	
		Humans have the right to modify the natural environment to suit their needs.		
		When humans interfere with nature it often produces disastrous consequences.		
		Human ingenuity will insure that we do not make the Earth unlivable.		
		Humans are seriously abusing the environment.		
		The Earth has plenty of natural resources if we just learn how to develop them.		
Plants and animals have as much right as humans to exist.				

		<p>The balance of nature is strong enough to cope with the impacts of modern industrial nations.</p> <p>Despite our special abilities, humans are still subject to the laws of nature.</p> <p>The so-called “ecological crisis” facing humankind has been greatly exaggerated.</p> <p>The Earth is like a spaceship with very limited room and resources.</p> <p>Humans were meant to rule over the rest of nature.</p> <p>The balance of nature is very delicate and easily upset.</p> <p>Humans will eventually learn enough about how nature works to be able to control it.</p> <p>If things continue on their present course, we will soon experience a major ecological catastrophe</p>	
Awareness	National Environmental Literacy/Awareness Survey: Attitude & Disposition Subsection [141]	<p>Protecting the environment is critically important for the survival of future generations</p> <p>Protecting the environment is equally important as job creation</p> <p>Environmental education should be a necessary component of primary and secondary school education</p> <p>Recycling waste is a benefit to both the natural environment and the economy</p> <p>Environmental laws are properly enforced in Europe</p>	<p>1 = Strongly disagree</p> <p>2 = Disagree</p> <p>3 = Neither</p> <p>4 = Agree</p> <p>5 = Strongly agree</p>
Knowledge	NEETF/Roper - Adapted for a European sample [62]	In general, how much do you feel you know about environmental issues and problems?	<p>A lot</p> <p>A fair amount</p> <p>Only a little</p> <p>Practically nothing</p> <p>Don't Know</p>

		<p>There are many kinds of animals and plants, and they live in many different types of environments. What is the word used to describe this idea?</p>	<p>Multiplicity Biodiversity Socio-economics Evolution Don't Know</p>
		<p>Carbon monoxide is a major contributor to air pollution in Europe. Which of the following is the biggest source of carbon monoxide?</p>	<p>Factories and businesses People breathing Motor vehicles Trees Don't know</p>
		<p>How is most electricity in Europe generated?</p>	<p>By burning oil, coal and wood With nuclear power Through solar energy By hydro electric power plants Don't know</p>
		<p>What is the most common cause of pollution of streams, rivers and oceans?</p>	<p>Dumping of garbage by cities Surface water running off yards, city streets, paved lots and farm fields. Trask washed into the ocean from beaches Waste dumped by factories Don't Know</p>
		<p>Which of the following is a renewable resource?</p>	<p>Oil Iron Ore Trees Coal Don't know</p>
		<p>Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?</p>	<p>Acid rain Global warming Sudden changes in temperature Harmful cancer-causing sunlight Don't know</p>

		Where does most of the waste in the Europe end up?	Oceans Incinerators Recycling Centres Landfills Don't know
		Which of the following household wastes is considered a hazardous waste?	Plastic Packaging Glass Batteries Spoiled Food Don't know
		What is the most common reason that an animal species becomes extinct?	Pesticides are killing them Their habitats are being destroyed by humans There is too much hunting There are climate changes that affect them Don't Know
Action	Action subscale [111]	How often do you do the following:	
		Turn off the lights at home when they are not in use	0 = All the time 1 = Some of the time 2 = Rarely 3 = Never
		Pick up trash that I find outside	
		Ask others about things I can do about environmental problems.	
		Turn off the water when it is not in use	
		Close the refrigerator door while I decide what to get out of it	
Recycle at home			
Skills	Action Planning – Cognitive skill action planning sub-section [144]	I will use multi-media, such as newspapers, magazines, or the Internet to obtain information related to environmental issues.	1 = Strongly disagree 2 = Disagree 3 = Neither 4 = Agree 5 = Strongly agree
		I am able to identify environmental problems and find solutions to them	
		I can integrate different viewpoints on environmental issues and form my personal opinions.	

		I can reflect on my own behaviour about the social and environmental impacts	
		I am able to communicate relevant environmental-related information to others.	
		I know how to use appropriate channels to promote environmental knowledge and environmental friendly policies.	
	Critical Analysis - Adapted defining issues test [[145] adapted by [111])	Striped bass is a popular sportfish and is also harvested for food. anglers and commercial fishers are spending more time fishing for striped bass than they used to but are catching fewer and smaller striped bass than in the past. Daniel is in charge of making sure that fishing for striped bass is sustainable over time. therefore, Daniel must think about many issues to determine the best solution to this challenge. What are the most important questions to ask as you begin to solve this problem?	
		What has been the number of new striped bass entering the population each year?	Rate1-5
		What size are the striped bass that can successfully reproduce?	
		What are the most important foods striped bass eat?	
		Do predators eat juvenile striped bass	
		What do striped bass fishers use for bait?	

4.3.1.1 Short-Form Measure of Environmental Literacy

As noted above, longer measures of environmental literacy risk increased rates of attrition and non-response bias. To mitigate against this a short-form version of the EVIDENT Environmental Literacy Survey was developed. This consists of 27 questions, again based on the AKASA model. All individual questions included are presented in Table 14 below. This version differs from the long-form version in the knowledge, attitude and action sections. For the knowledge section, five key questions from the NEETF/Roper measure were used, with only those deemed most relevant to the EVIDENT project retained. For attitude, the short-form version of the National Environment Paradigm was included [146] to reduce response effort. In addition, the section examining values was omitted in the short-form survey as many aspects of values are thought to be considered within the National Environment Paradigm questions. Minimal reductions were also made to the skills section with one action planning question removed due to perceived overlap with other questions in the survey. As such, while this shortened version of the survey still considers all aspects of AKASA and addresses the past limitations noted in the sections above, its shorter length may facilitate its inclusion in surveys which also include other areas of analysis.

Table 14: EVIDENT Short-Form Environmental Literacy Survey

Aspect of Environmental Literacy	Measure Employed	Questions	Response Options
Attitude	Willingness/Behavioural Intention [142]	If there is a power-saving measure that can help you reduce your electricity bills, but this measure may change your lifestyle habits. Do you think you might stick to it?	Basically impossible. Can stick for a while. Can stick.
	NEPS: Shortened 6 item scale [146]	Plants and animals have as much right as humans to exist.	1 = Strongly disagree 2 = Disagree 3 = Neither 4 = Agree 5 = Strongly agree
		The Earth is like a spaceship with very limited room and resources.	
		Humans were meant to rule over the rest of nature.	
		The balance of nature is very delicate and easily upset.	
		Modifying the environment for human use seldom causes serious problems	
There are no limits to growth for places like Europe			
Awareness	National Environmental Literacy/Awareness Survey: Attitude & Disposition Subsection [141]	Protecting the environment is critically important for the survival of future generations	1 = Strongly disagree 2 = Disagree 3 = Neither 4 = Agree 5 = Strongly agree
		Protecting the environment is equally important as job creation	
		Environmental education should be a necessary component of primary and secondary school education	
		Recycling waste is a benefit to both the natural environment and the economy	
		Environmental laws are properly enforced in Europe	
Knowledge	NEETF/Roper [62]	Carbon monoxide is a major contributor to air pollution in Europe. Which of the following is the biggest source of carbon monoxide?	Factories and businesses People breathing Motor vehicles Trees Don't know

		What is the most common cause of pollution of streams, rivers and oceans?	Dumping of waste by cities Surface water running off yards, city streets, paved areas and farm fields. Trask washed into the ocean from beaches Waste dumped by factories Don't Know
		Which of the following is a renewable resource?	Oil Iron Ore Trees Coal Don't know
		Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?	Acid rain Global warming Sudden changes in temperature Harmful cancer-causing sunlight Don't know
		Where does most of the waste in the Europe end up?	Oceans Incinerators Recycling Centres Landfills Don't know
Action	Action subscale [111]	How often do you do the following:	
		Turn off the lights at home when they are not in use	0 = All the time 1 = Some of the time 2 = Rarely 3 = Never
		Pick up trash that I find outside	
		Ask others about things I can do about environmental problems.	
		Turn off the water when it is not in use	
		Close the refrigerator door while I decide what to get out of it	
		Recycle at home	

Skills	Cognitive skill action planning sub-section [144]	<p>I will use multi-media, such as newspapers, magazines, or the Internet to obtain information related to environmental issues.</p> <p>I am able to identify environmental problems and find solutions to them</p> <p>I can integrate different viewpoints on environmental issues and form my personal opinions.</p> <p>I am able to communicate relevant environmental-related information to others.</p>	<p>1 = Strongly disagree</p> <p>2 = Disagree</p> <p>3 = Neither</p> <p>4 = Agree</p> <p>5 = Strongly agree</p>
	Adapted defining issues test [111]	<p>Striped bass is a popular sportfish and is also harvested for food. anglers and commercial fishers are spending more time fishing for striped bass than they used to but are catching fewer and smaller striped bass than in the past. daniel Pinder is in charge of making sure that fishing for striped bass is sustainable over time. therefore, daniel must think about many issues to determine the best solution to this challenge. What are the most important questions to ask as you begin to solve this problem?</p> <p>What has been the number of new striped bass entering the population each year?</p> <p>What size are the striped bass that can successfully reproduce?</p> <p>What are the most important foods striped bass eat?</p> <p>Do predators eat juvenile striped bass</p> <p>What do striped bass fishers use for bait?</p>	Rate1-5

5. Reconciling financial and environmental literacy

5.1 Theoretical framework and motivation

It is well documented in the literature that behavioural biases, financial and environmental literacy play an important role in decision-making. To further understand their impact and most importantly to estimate their combined impact on the decision-making process, we propose in this section a quasi-experiment in the framework of the marginal price bias.

More specifically, nonlinear energy pricing complicate economic decisions by providing multiple marginal prices for the same service. A central assumption in economics is that firms and consumers are rational and that optimize given the available information which in the current example is a marginal pricing scheme. For example, consider consumers that face nonlinear tariffs in their energy consumption. These nonlinear tariffs are usually induced to optimize the intraday use of energy and to decrease consumption during peak times. The main assumption for this proposed policy is that consumers optimize their consumption with respect to the price which implicitly assumes that the realized price equals the perceived price. Furthermore, this marginal price bias has found to apply to other domains as for example on optimal taxation. In this regard, the implicit assumption is that taxpayers respond to their marginal tax rate by correctly estimating the right tax that applies to their income [147][148][149].

In the same vein, empirical studies in economics and subsequent policy recommendations generally take this rationality assumption as given when estimating the impact of various policies on a variety of domains that include nonlinear pricing schemes, subsidy, and tax rates. However, evidence from many recent studies suggests that consumers may not respond to nonlinear pricing schemes as the standard economic theory assumes. Many surveys find that few people understand the complexity of a nonlinear price. Many of these estimations took place in laboratory experiments, and results show cognitive difficulty in understanding nonlinear price systems while subjects tend to respond to an average price. While these results may have important welfare implications, still there is no clear empirical evidence on this question.

In the proposed quasi-experiment, we design a framework to uncover consumers' perceived price of nonlinear price schedules. We assume that for consumers that don't use marginal prices in their estimation, they may use average price as an approximation of marginal price if the cognitive cost of understanding complex pricing is substantial. This suboptimization is described as "schmeduling" by Liebman and Zeckhauser (2004) [150].

5.2 Design of the survey

In this part of the deliverable, we present the main framework of the proposed quasi-experiment. As it will be apparent later, the quasi-experiment is closely related to use cases 4 and 5 "Relation of energy consumption behavioural biases with consumers' financial literacy level" and "Exploit energy demand curves" respectively. The experiment is designed in a way to elicit consumers' perceptions about different pricing schemes and to relate findings with potential behavioural biases and the participants' financial and environmental literacy level. The implementation of the experiment is expected to take place through the EVIDENT's platform and its design is as follows:

1st step: Participants answer a small set of questions for collecting demographic data

2nd step: Participants answer a small set of questions related to biases

3rd step: Participants answer a small set of questions related to financial literacy

4th step: Participants answer a small set of questions related to environmental literacy

5th step: Participants answer a small set of questions related to price perceptions.

The overall response time for a participant to complete the quasi-experiment will be no more than 20 minutes.

5.2.1 Description of step 5

In the beginning, the participant receives a message *“Assuming that your yearly energy consumption is exactly 6,000kWh, which one of the following tariffs would you choose as the most cost effective?”* In order for the message to be as realistic as possible, will be slightly adjusted with respect to the specifics of the energy market in the country that the experiment is being implemented. For example, in countries where the average energy consumption of a household is higher, the energy amount will be considered to adjust accordingly.

Then, the participants receive on their screen different sets of tariffs. These different sets change in complexity, for example, one has to choose between an average price and a two-tier tariff scheme, while next is asked to choose between an average price and a three-tier tariff scheme. We may also consider increasing the complexity by adding four tiers or more. It is important to note, that we assume that for consumers that do not use marginal prices in their estimation, they may use average price as an approximation of marginal price and this is the main reason that each option includes both an average and a marginal price.

Also, different assumptions are made for the energy consumption threshold that triggers a change in the price. For example, for some options, energy consumption is evenly distributed between the tiers. In the two-tier pricing scheme, 3,000kWh are assigned in the first tier and the rest 3,000kWh of the total 6,000 kWh are assigned in the second tier (see for example option 1 below). Another option includes more kWh in the first tier and less in the second tier and vice versa (see for example option 3 and option 5 below respectively). This gradually increasing complexity can act as a proxy variable for measuring consumers' inattention.

It is important to note that among all potential sets of questions presented below, each participant is randomly assigned to only a few. This is so for keeping completion time low and at the same time to minimize attrition. One final note is that the order of appearance of the options to the participants will be randomly assigned.

Different tariff types (bold indicates the most cost-effective plan)

Less complex options

Option 1

- a. 0.10 €/kWh for all consumed kwh

- b. **0.08 €/kWh <3,000 kWh and 0.11 €/kWh > 3,001kWh**

Option 2

- a. **0.10 €/kWh for all consumed kWh**
b. 0.05 €/kWh <3,000 kWh and 0.16 €/kWh > 3,001 kWh

Option 3

- a. 0.10 €/kWh for all consumed kWh
b. **0.065 €/kWh <3,500 kWh and 0.135 €/kWh > 3,501kWh**

Option 4

- a. **0.10 €/kWh for all consumed kWh**
b. 0.065 €/kWh <3,500 kWh and 0.155 €/kWh > 3,501kWh

Option 5

- a. 0.10 €/kWh for all consumed kWh
b. **0.09 €/kWh <2,000 kWh and 0.11 €/kWh > 2,001kWh**

Option 6

- a. **0.10 €/kWh for all consumed kWh**
b. 0.055 €/kWh <2,000 kWh and 0.14 €/kWh > 2,001kWh

Each participant will be randomly assigned between options 1 and 2, options 3 and 4, and options 5 and 6.

More complex optionsEven distribution of energy consumption between tiers

Option 7

- a. **0.10 €/kWh for all consumed kWh**
b. 0.081 €/kWh <2,000 kWh 0.09 for 2,001kWh - 4,000kWh and 0.135 €/kWh for the last 2,000kWh

Option 8

- a. **0.10 €/kWh for all consumed kWh**
b. 0.079 €/kWh <2,000 kWh 0.09 for 2,001kWh - 4,000kWh and 0.133 €/kWh for the last 2,000kWh

Option 9

- a. 0.10 €/kWh for all consumed kWh
b. **0.079 €/kWh <2,000 kWh 0.09 for 2,001kWh - 4,000kWh and 0.12 €/kWh for the last 2,000kWh**

Option 10

- a. **0.10 €/kWh for all consumed kWh**
- b. 0.059 €/kWh <2,000 kWh 0.09 for 2,001kWh - 4,000kWh and 0.152 €/kWh for the last 2,000kWh

Option 11

- a. 0.10 €/kWh for all consumed kWh
- b. **0.09 €/kWh <2,000 kWh 0.09 for 2,001kWh - 4,000kWh and 0.106 €/kWh for the last 2,000kWh**

Different distribution of energy consumption between tiers

Option 12

- a. **0.10 €/kWh for all consumed kWh**
- b. 0.08 €/kWh <3,500 kWh 0.09 for 3,501kWh - 4,500kWh and 0.159 €/kWh for the last 1,500kWh

Option 13

- a. 0.10 €/kWh for all consumed kWh
- b. **0.08 €/kWh <3,500 kWh 0.09 for 3,501kWh - 4,500kWh and 0.12 €/kWh for the last 1,500kWh**

Option 14

- a. **0.10 €/kWh for all consumed kWh**
- b. 0.08 €/kWh <1,500 kWh 0.09 for 1,501kWh - 3,500kWh and 0.20 €/kWh for the last 1,500kWh

Option 15

- a. **0.10 €/kWh for all consumed kWh**
- b. 0.08 €/kWh <1,500 kWh 0.095 for 1,501kWh - 2,500kWh and 0.12 €/kWh for the last 3,500kWh

As before each participant is randomly assigned between options 7 to 11 and between options 12 to 15.

6. Conclusions

The deliverable is structured into 3 interdependent sections. The first section (section 3) refers to the main behavioural biases that may affect decision-making in energy efficiency while at the same time presenting the concept of financial literacy among their assessment tools. As the final part of the section, a new framework to measure the level of financial literacy and estimate the behaviour of the people regarding the risks they ought to take in their financial decisions is presented consisted of 19 items and incorporated into three different categories named Skills, Attitude and behaviour, and Behavioural Biases.

The next section (section 4) analyses the concept of environmental literacy providing an extensive overview of human behaviour and the impact of their actions on both local and global environments. Following the related literature proposes tools for empirically assessing their environmental literacy level consisted of 18 items organised into 7 logical phases named Self-assessment, Financial knowledge, Technology knowledge, Self-management, Present bias, Risk and Overconfidence and 3 categories knowledge and Skills, Attitude and behaviour, and Behavioural Biases.

Finally, in the last section (section 5), the deliverable proposes the design of a quasi-experiment that estimates how consumers respond to average and marginal prices considering the potential presence of biases as well participants' financial and environmental literacy level. The proposed quasi-experiment it's expected to uncover consumers' perceived price of nonlinear price schedules.

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