

TECH FOR NET ZERO: DIGITAL SOLUTIONS FOR A SUSTAINABLE PLANET

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DOI: <https://doi.org/10.64558/blp/352864tmvzfb>

ABSTRACT

With the advent of climatic conditions having changed a lot, an urgent need is felt, which necessitates technological transformation and, accordingly, behavioural adoption. It is true that the needs of sustainability of this planet and keeping climatic conditions under control, adopting digital tools like smart grid, IoT, or even blockchain can help a long way, but, its dependence on human acceptance and widespread human adoption is very important. In today's time, convincing customers based on just factual statements or simple economic arguments is less effective; instead, few facilities or statements that add to a more deeply involved cognitive process are proven to be more effective. This paper tries to address the issue of achieving net zero, but, not just with the digital technological adoptions of tools, but it also integrates it with change in propositions of the behavioural segment of humans through streams like neuromarketing and neuroeconomics.

By strategically utilising neuro commands that directly tap of Nobel Lauret ideas like loss aversion, hyperbolic discounting, and social proof, these choices are difficult to be missed as they give a sense of achievement immediately and are more socially compelling. Bringing real-world examples from building energy efficiency and national power generation planning, this research

paper can substantially increase user interest and therefore their involvement in the said way of activity. This ultimately supports user engagement and transition to net - zero future.

Keywords: Digital Sustainability, Neuromarketing, Neuroeconomics, Behaviour Change, Green Technology, IoT, AI, Nudging, Energy Efficiency, Carbon Emissions.

INTRODUCTION

The vitality of the planet Earth

The sixth assessment report of the Intergovernmental panel on climate change (IPCC 2022,2023) has given a clear message that human activities have warmed the planet at a very high rate, which is ultimately causing irreversible changes and destruction of our natural resources, impacting our ocean, atmosphere, biosphere, and cryosphere. Year 2023 was declared as the hottest year, and the heat it created had a severe impact on climate change (World Meteorological Organisation 2024).

The concept of Net Zero – balancing development with protecting the planet.

The sunlight that comes from the sun has a short wavelength, then it enters the earth's atmosphere and strikes the surface of the earth. As the light coming from the sun has higher energy and temperature, some of its portion gets absorbed by the planet's surface and some gets reflected

into the environment. Now, as in the environment there exist different Greenhouse gases (GHGs) ,these gases absorb infrared rays, and then these gases radiate back the infrared rays. These infrared rays are not visible, but felt in the form of heat. So as these rays get reflected in the atmosphere from GHGs, they increase the overall temperature of the Earth.

The main greenhouse gases (GHGs) include:

- * Water vapor (H₂O)
- * Carbon dioxide (CO₂)
- * Methane (CH₄)
- * Nitrous oxide (N₂O)
- * Ozone (O₃) at ground level

Fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆), and nitrogen trifluoride (NF₃). Green houses gases (GHGs) get emitted during the burning of fossil fuels, factory processes, electricity, heat etc.

We are in the critical times of serving humanity, which in fact has an important role in climate change. The causes of the generation of greenhouse gases are also closely linked to the development process of the countries. As development involves urbanisation, industrialization etc and these process leads to the generation of GHGs. So, in order to continue the development and balance the climate, **the concept of Net zero emerged**. In net zero, the amount of GHGs which are getting produced due to various reasons should be **netted** against the ways in

which the GHGs are getting reduced using ways like afforestation, using renewable resources of energy or choosing digital technologies for doing our tasks rather than opting for conventional ways , this path of going digital ,helps us in a way let save in the emission of GHGs from ways which leads to emission of GHG.

The World Economic Forum (WEF) has highlighted the importance of” Digital Solutions for a Sustainable Planet. "It includes some of the ways that include smart grids, precision agriculture, and circular economy platforms. As these ways are suggestive of improving the development path and reducing the pollution of GHGs, they help us move towards the goal of Net Zero.

Bottleneck – Behavioural Gap

Still significant gap exists in the addressing of this problem as a crucial aspect of human behaviour is kept aloof. Brynjolfsson and McAfee (2014) had argued that the pace of technological development is faster than the behavioural adoption. This is also particularly in the cases where the benefits of choosing the path of sustainability, like choosing precision agriculture or Iot may be seen in the future, but the cost charged to the consumer is immediate. In fact, a recent report, which was published in 2024 by the Behavioural Insights team found that the strategies that promote consumers to choose sustainable pathways or ethical appeal made to them, or even environmental governance ideas, could not produce good results because all these ways have a thought process behind it that the individuals are very logical and

rational and chase for maximum utility. But after decades of research in psychology and behavioural economics, particularly after well-known contributions from Kahneman (2011, it was found that not all the time humans think rationally, and when making decisions concept of emotional biases or social pressures gets generated many times, which moves the decision from most rational to most acceptable in the prevalent conditions. Here, the role of cognitive biases also pops in.

Let the neural layer led the decision to take the lead

Considering there is a significant gap between technological development and its adoption, popular studies like neuromarketing and neuroeconomics have suggested ways that give direct **stimulation to rain wires** can lead to the usage of technologies, which finally helps in to the achieving the results.

By looking into the digital adoption from the lens of neuromarketing ,it gives direction how brain responds to stimulating shows or advertisement and which part of the brain gets activated ,so with better understanding from the principles of neuromarketing a better way of pitching the technology can be adopted which actually hits the most and make a proposition to the brain that compels it to choose digital technologies for sustainable development. As neuromarketing shows which part got activated while the digital solutions are presented, while neuroeconomics tells which part gets stimulated when the brain is actually taking a decision involving the mid brain, which mainly talks about emotions, and the frontal cortex region,

which takes care of the cognitive action of the brain. Thus, neuroeconomics tries to find out how risk-return analysis is done and how the final decision is arrived at after careful analysis (Glimcher & Fehr, 2013).

Thus, when trying to understand the intricacies of the brain, and taking our understanding to the microscopic level, it shows that there are major barriers that stop us from making decisions that include-

- **Loss aversion**, which says that an individual is psychologically more **sensitive** towards a **loss** as compared to the pleasure of gaining or winning anything. (Tversky & Kahneman, 1991), thus, in order to support the people, maintain the status quo, many times, to avoid losses, as it is more painful to them.
- **Hyperbolic Discounting**- Liasson in 1977 , has shown that people are more interested in immediate small gains rather than huge gains in the future.- that even acts as a major hindrance in choosing a sustainable solution now, as immediate cost is involved.
- **Social Proof** – It highlights how social behaviour influences individuals' behaviour (Cialdini, 2007).

In fact, in the latest work of Li et al. (2024) in Suzhou, Jiangsu province, China, where he used AI powered nudge messages to stimulate people for more usage of public transport. Thus, the study proposed that by increasing the usage of AI messages, it increased a 28% of public transport usage.

Thus, this paper keeps in the successful strategies as a major torch bearer for

guiding principles in designing strategies to promote digital technologies which help in achieving net-zero emission.

Research Question and Paper Structure

Thus, this paper closely organises the themes from the core concepts of neuromarketing and neuroeconomics and integrates it with the design pattern of the digital methodologies so that the actual deployment of the technologies can happen at the field that also promotes pro-environmental growth and support ideas.

We there by propose a very structured framework that unites two ideas: a **"neuro-layer" structured approach and digital sustainability tools**, and validate its potential with a case study on home energy management, supported by empirical evidence from building and national-level energy studies.

To answer how the paper is structured, its Section 2 gives a highlight on literature review, which provides digital sustainability solutions and what brain or thinking principles actually needs to be checked and how it need to be framed properly, keeping an idea of both, backed by the latest research.

Section 3 gives an introduction to a framework that takes into account the integration as the Neuro-Digital Sustainability Framework; moreover, a methodologies are also addressed, which are suggested to be three- phased, and it is also backed by the current advances in the field of Generative AI and how its features are getting more and more personalised.

Section 4 showcases a clear in-depth case

study where a framework is given for the Home Energy

Management System that gives a picture of how a decision taken serves well in line with brain engaging and technology proven, informed by 2024 field trials.

Section 5 gives insights on what are the broader implications of the studies and solutions suggested in the study, as well as the ethical challenges and implications, along with the scope of future scope of research.

Finally, Section 6 highlights the summarised version of what has been discussed in the paper with proper argument and its importance.

LITERATURE REVIEW

The evolving landscape of Digital Sustainability (2023-25)

The idea of using digital solution is to reduce the GHGs, which otherwise would have emitted in normal projected ways of activity ,however by bringing in the idea of using digital technologies the efficiency of work gets improved, duplicity of the work is avoided and ultimately there is impact on emission content of gases .But making system just won't finish the task ,but ,making it smarter more adaptive is also needs to be addressed. So keeping all these agendas into the real context research is getting supported and technologies are getting developed based on these lines.

Building Smart grids and efficient Energy systems

Earlier in old times electricity use to flow from source to demand points, without any track on production and

consumption of electricity, but with the advent of smart grids the idea of keeping a track from production and consumption of energy came more evident. It is particularly important to track if sufficient sunlight is there to generate certain amount of electricity or how much is the energy which got produced from wind energy. As these sources of energy are nature oriented, hence it is very important to keep a close track on it. With the introduction of smart grids which uses tools like AI, Iot, smart meters etc it establishes a channel of two ways network for the electricity and keeps a track on demand and supply based on its producers and consumers dynamically (Gharavi & Ghafurian, 2011).

In the recent study of Schmidt et al. in 2023, it was found that Ai can predict the renewable generation with over 95% accuracy well in advance for 3 days. This help in increased reliance on smart grids. Airaksinen and Matilainen (2011) gives an important point where they show that its good to have energy efficient buildings, but a very important critical fact remains untouched when the building is getting make where at so many points GHGs get emitted. Thus, carbon embodied during its construction, build up or even transport is huge and thus become a dominant part of building's lifetime carbon foot print. So if we can incorporate digital tools into the process, it gives high operational efficiency and gives a good systemic view about raw material and supply chain system too. As per the meta-analysis by Chan et al, it was confirmed that the total amount of embodied carbon was 50% of total lifecycle carbon of new energy efficient buildings. Hence, this crucial part too

needs to be addressed. In a recent analysis report of Kanugrahan et al. (2022), on Indonesian power sector, it was shown that too much reliance on controlling the price or expenses and less emphasis on structural and behavioural considerations leads to poor efficiency with respect to finance and capacity utilisation and thus ultimately the core idea of carbon reduction remains unrealised.

Precision Agriculture and AI

Agriculture remains a major sector which contribute to major water, and source of nutrient runoff and emissions. In order to monitor soil moisture content, crop health and even pest presence at hyper-localised level, a news ways are getting adopted using precision agriculture where the idea of agriculture does not remain restricted to old traditional ways of farming, but, it adopts a way like drones, satellite imaginary, and even IoT sensors (Zhang et al., 2020). A 2023 review in Nature Sustainability by Gupta et al. also points out to the fact where how yield and usage of water and nutrient got impacted because of precision agriculture. The review article said that the yield got increased by 5-10% an reduced usage of wate and nutrients by 20-25%. But here many farmers may not opt it because of behaviour driven factors making the farmers away from data driven technologies and being dependent on traditional knowledge. Infact, World bank had showed that if the data driven messages can be communicated through simple local dialects and with the information of social proof, whereby neighbouring villages adopting the technology is mentioned then, it increased the adoption of technology by 40%.

The Circular Economy, Blockchain, and AI

In circular economy the product is utilised as long as possible and not discarding them just after few years. Here the idea is to reuse, repair or recycle everything **and** reduce wastage of resources.

Blockchain can be a excellent partner for recording every step of the product journey from where it is made to where it is recycled. This is known as digital product passport. Here the customer and companies with the help of keeping a digital record would know from what all raw materials the final product is made up of and recycle of the product can also be tracked (Kshetri, 2018).

In fact, it was found in 2025 after pilot study was done by European Union, that practices like using block chain and digital product passport usage increased the recycle of materials by about 30%.

AI-based resale platforms (Rodriguez et al., 2024) with camera and usage of smart algorithm can help predict the resale value of the product-thus bring in endowment effect-, by assessing the condition of the product. This approach made people more interesting into it and made them go for recycle or resale. This ultimately increased the life span of the product.

Thus, here we see how digital tools are powerful enablers of technicality adoption. Even going a step ahead into it, it increases return on environment got increased as the product's life span got increased, thus by targeting the behavioural segment of human, it can be seen clearly that adoption process emphasis on should be technological adoption as end goal but the route of it should be through psychological and

sociological ways.

The Architecture of Choice: Neuromarketing and Neuroeconomics

So, in order to tap the behavioural segment of the consumers or technology adopters, it is important that we go one step ahead of tapping the neural component of the brain directly to the point which impacts the most in the decision making. Recent studies have provided a rare insight which can help us give a way out for bringing the thought of technological adoption in practice.

Foundational Principles from Behavioural Economics

- **Loss aversion:** - As per the Prospect theory of Kahneman and Tversky, 1979, loss aversion theory says that people are more sensitive towards losses than for equal quantity of winning amount. Say loosing \$50 is more painful and hits with higher intensity then winning an equal amount. Moreover, in one neuroimaging study conducted in 2023 by Park et al has confirmed that the amygdala an important structure in brain gets highly activated in cases of direct losses, infact he went one step ahead and confirmed that amygdala gets activated highly even due to anticipation of future losses as well. The study also addressed that people resist to adopt to new technology and remain stick to inefficient technologies, fearing that the change in existing tech can lead to losses in the future.
- **Hyperbolic Discounting:** When people make decision about the future rewards, they often try to be patient .

But, often people in search of future rewards procrastinate things. Thus in order to make people choose the route say for example digital technologies, they should be offered a immediate rewards so that even a smaller reward at present would be better than larger reward later. In 2024 paper in Science from O'Doherty lab who utilised fMRI for showing which part of the brain gets activated during decision making found that when brain is satisfied and happy with immediate reward then limbic system of the brain gets activated. Similarly when long term rewards are offered to brain the lateral pre frontal cortex (pFC) of the brain gets activated. Pre frontal cortex is basically involved in the cognitive process of the brain. So the way to approach ,for letting people adopt the new technologies, the best is to associate the digital technologies with the immediate rewards , so that the limbic system gets activated.

- **Social Proof:** Rober Cialdini (2007), has tried to address the key of bringing in the social perspective and its key principles of influence. A per the large scale study conducted in 2023 by Garcia et al. it was found that the putting a social badge had a very good impact on the adoption among people. As the users were given green badge based on their work of planting trees, reduced plastic usage etc, with this badge showcased has motivated other to pose it in the social media. So when the people showcasing their social badge it motivated their friend and acquaintances to show them and they also started practicing the same to earn that badge – this is called

normative social influence. Hence, because of this aspect 18% increase in the activity seen among their network.

- **The Pain of Paying:** This concept was observed by Prelec and Loewenstein in 1988, where they had observed that when people are asked to pay ,their neural network inside the brain gets activated and the region inside the brain with which it is associated is with pain and discomfort. In 2024, field experiment was conducted by fintech company , how encouraging and sustainable an idea can be if the payments demanded are nearly “invisible” for the task which is important and has long term affects. — for example, rounding up a \$97.50 purchase to \$100, and donating the extra \$2.50 toward carbon offset projects can be a good idea of involving public in big way by contributing to bare minimum and the activity like carbon offsetting has long term affects.

Neuroscientific Evidence and the Rise of Neuromarketing Tech.

Neuromarketing and neuroeconomics have direct relation with which a behavioural segment can be addressed and by welcoming the ideas and findings from both the stream, process of doing things like stimulus for adoption of policies or technologies can be learnt which helps in better adoption and gives good results.

- **Beyond fMRI and EEG:** Good results can be obtained by utilising technologies like fMRI and EEG, but these technologies can be costly and performing test requires a whole setup which might be something not everyone can afford. However, with

the advent of new technologies like wearable eye tracking glasses or even Galvani skin response wristbands are getting used to check the intensity of stimulus. These instruments have good user engagement as well as emotional arousal can be tracked based on the skin, eye movements for checking the adoption of digital sustainability (Harris, 2024).

- **The Dual-System Model:** Learning from (Kahneman, 2011) on Neuroeconomics projects an idea which says that the brain consists of two competing systems:

System 1 is a fast, intuitive, emotional

System 2 is a slow, deliberative, logical system.

A study review in 2025 in Nature Behaviour argues the if the idea of sustainability can be taken by getting into system 1, that is if the choice of being sustainable becomes the default choice and later system 2 can be used for giving post-hoc justification and in-turn building long term values with respect to the idea of sustainability.

The Integrated Neuro-Digital Sustainability Framework

It can be clearly seen that there exists a clear gap between the actual technological potential and how the person is reacting to adoption of the technology i.e. the behaviour aspect. So, in order to address this gap a three phased structured framework is proposed, so that the better results can be obtained with respect to technology adoption. Also, these strategies also take the help of AI techs

usage for making new technology adoption easy.

Phase 1: Diagnosis & Behavioural Friction Analysis

The first phase of this study involves a very deep analysis of knowing the behavioural aspect and using those commands or sentence which actually brings a change

Step 1: Define the Target Behaviour:

Moving away from giving vague goals or commands say for example when it is said to be more sustainable, it creates a very less emotional or motivational idea into the brain, which is very less intriguing. Instead of this if the statement or idea could be more specific, measurable, actionable, realistic, and time-bound, popularly known as 'SMART' behaviours, then it really triggers the neural aspect of the brain as they even look more relatable, achievable and hence actionable.

Examples: For example, a statement on AC like "Setting the AC at 24 degrees, will increase the life of AC."

Step 2: Demarcating a clear dominating cognitive behavioural aspect

So for every target behaviour, trying to address the primary neuroeconomic barrier, so that it can be worked on in the next step. Is it:

- **Loss Aversion & Status Quo Bias?** (for example, not willing to opt for thermostat settings)
- **Hyperbolic Discounting?** (e.g., not willing to pay for a premium on order to have an energy- efficient appliance)
- **Lack of Social Proof?** (e.g., impact of

one person adopting to social group habits)

- **Pain of Paying?** (e.g., paying a high amount upfront cost for adopting a technology)
- **Endowment Effect?** (e.g., overvaluing a self owned car which got old and inefficient and despite these shortcomings willing to replace it)

Step 3: User Persona and Journey Mapping:

Creating a clear user persona and identifying their journey during the time of their interaction with the technology will give a good idea of knowing whether these technologies are really triggering the emotions which can really make them go for the purchase. Identify "moments of realisation" where the behavioral friction is highest and intervention is most critical. Basically different generative AI tool can be used to analyse the customer's transcript and even the ideas they have shared in the social media can give a good insight of view points of the customers.

Phase 2: Technology-Neuro Principle Mapping and AI

Table 1

Loss Aversion	The people are more sensitive emotionally towards losing as compared to winning or making a gain.	Smart Home Energy Dashboard,	By choosing "You are losing \$0.02/minute." instead of saying that "You just saved \$5" on the dynamic display of "Carbon Waste Meter" that visualizes real-time emissions and give the report dynamically based on usage. Utilising Generative AI to make a very personalized and messages which give a message that they may make a loss if some actions are not taken. For example : <i>"Ram, your monthly expense bill is off track and you just had wasted \$45 this month—that's like throwing away a movie night with a family and yes dinner at Home now and not at hotel !!"</i>
Hyperbolic Discounting	When it comes to getting future rewards, people are reluctant to stretch and show patience, but, instead they are happy to work with the immediate gratification	Sustainable Mobility Apps, Recycling Incentive Platforms, Energy Apps	Offering instant micro-rewards :like " +50 Green Points! Is credited as you took the public transport. Now, you are just 50 Green points away from getting 1\$." Bringing gamification into the picture by allocating badges or even creating a leadership board whose data gets updated on real time as per the sustainable action taken by the customer, trying to give instant cash rewards by integrating the whole system with the payment system.
Social Proof	Individuals get influence by their	Community Energy	By showcasing a comparative messaging where a comparative scenario is done among the whole area like:
	social group and acts according what is more acceptable	Platforms, Enerfy meter, calories	"You used 15% more electricity than the average household consumption in your area." Giving what is really popular in the society so that people also can choose similar sustainable choices: "More than 90% of people are using stairs till 4th floor."

	in the society as a whole.	meter.	Giving them a idea of how many calories got burnt with every floor they choose not to use lift.
Pain of Paying	The expense done by making a payment creates a very bad impression or memory.	Solar Panel/ EV Charge r Financ ing, Energy - Efficie ncy Retrofi ts	Instead of paying for a upfront amount as a whole for the cost of the project , instead a technological adoption can be done as a service first and we can start it with an offer of " Technology as-a-Service " models (e.g., " Solar-as-a- Service " by giving a monthly subscription). Using a strategy of “ pay as you save ”,whereby you are asked to make payment out of the savings. Suppose if the cost of the solar run light instrument is Rs 50 lakh electricity and consumption earlier was Rs 2 lakh, now suppose it goes to 1 lakh, so that Rs 1 lakh which got saved is used to pay,and hence it will do minimum 50 payments.
Endowment Effect	People attach more value to things which they own ,without attaching any logic to it.	Circula r Econo my & Resale Platfor ms	Using AI based tool to know about the resale value of the product, will help us in knowing the value through which the customer who earlier use to attach more value without the unknown reason ,now can understand and see things in clear perspective.
AI-Personalized Nudging	Utilising the power of give nudge messages intermittently for the individual will help in maximizing the impact.	All digital interfa ces.	Using generative AI for getting used as reinforcement way till those nudges start delivering the purpose. (Li et al., 2024)For example you intermittently can say if you choose not to use AC today you can save 1\$, or you will loose 2\$/week if you choose to take vehicle and not choosing to walk or use bicycle to go at nearest store near you which is within the periphery of 500 mtr.

Phase 3: Implementation, Testing, and Iterative Refinement

This phase measures whether the neuro-informed images are really effective by tapping whether the right place is really stimulated and also to see how that evolves over time.

- **Step 1: Implementation:** Adding messages and nudges to the real app, so that the real-time messages can be given to the people, so that the mindset and behavioural component can be targeted.
- **Step 2: A/B Testing and Empirical Validation:** After adding the critical nudges and generative messages, it needs to be checked whether the results desired were actually obtained or not.. So basically, how the tool which was working earlier say name it as 'A' be compared with the new app tool launched with the new features naming it as app 'B'. Depending on what needs to be measured can be worked on as a feature in the app say for example- how many people click through the app. How many have started adopting to this? What is the frequency of using it? How much electricity is consumed particularly in the peak times? What is the reselling propensity of the product?
- **Step 3:** Checking the work done :- By using the feedback loop, trying to see what all worked and what better strategies can be put in the system so that better results can be obtained.

Backdrop and Global Impediments:

A Global Home Energy Management Systems company keeping in focus to achieve a breakthrough in saving

greenhouse gas Energy by reducing the overuse of electricity and also empowering global customers in saving Money. The Enterprise spearheaded a profound idea to utilise the Mobile Application App or Chatbot by which a lot of electronic devices can be controlled, resulting in optimum utilisation of Energy.

So far, achieving results through the conventional way has given very mediocre success in comparison to the current & future Global Challenges so far Power Shortage is concerned.

Applying the Framework

Phase 1: Diagnosis: Problem Statement:

Target Behaviour: What makes People / Customers not heed the call to save Energy for the next generations?

- Target Behaviour of Consumer usage: Reduce electricity consumption, particularly during peak hours (4-8 PM on weekdays).
- Identified Frictions:
- Hyperbolic Discounting: Consumers are not motivated enough to save a perceivable small amount as a part of their Monthly bill savings.
- Lack of Salience & Abstract Data: Too much of the Technical viz: kWh and projected dollar amounts are not emotionally connected or incomprehensible for a customer.
- Lack of Social Proof: Consumers do not find enough social drives happening around them that drive them to follow other Users
- Status Quo Bias: For any customer natural motivation is to do nothing rather than read or execute something technical or Intangible.

Phase 2: Mapping and Redesign

The traditional app interface (showing kWh and monthly cost projections) is redesigned with a "neuro-layer."

- **Feature 1: The "Live Impact" Dashboard** (Leveraging Loss Aversion & Salience)
- **Traditional:** A line graph of daily energy use.
- **Neuro-Informed:** A central, color-coded gauge. When consumption is high, it glows red and shows a running counter: "Money Wasting: \$0.35...\$0.36..." When consumption is low, it glows green: "Money Saving: \$0.12...\$0.13..." Below this, a "Carbon Counter" shows equivalent CO₂ emissions in real-time (e.g., "= 2 kg of coal burned").
- **Feature 2:** Instant Gratification & Gamification (Leveraging Hyperbolic Discounting) Strengths of Your Design:
- **Micro-Validation:** Enforced chatbot or push notification turns an underrated act (pre-cooling) into a great victory.
- **Measurable Abstraction:** Yield convert abstract kWh into a "currency" the user can procure and invest, making savings feel more concrete.
- **Variable Rewards:** The unbreakable tendency of badges taps into the same Pleasure Hormone -driven feedback loops that make games addictive.

Enhanced & Additional Ideas:

- **The "Energy Avoided" Visualizer:**
- **Note Concept:** After a decisive

outcome in an energy-saving event, demonstrate a short animation. "You're saving enough energy to power 25 light tube lights for an hour!" or "You charged 220 smartphones!" This makes the impact visually immediate and understandable.

- **Neuro-Principle: Permanent Effect.** – customer has a better memory for the concepts or numbers which are concrete and clear and not something a very vague or abstract concept.

- **Making Streaks & "Insurance":**

- **Concept:** Introducing a "12-Day Streak" badge. If a user loses on the 8th day, then he will get another life, using the insurance points, so that he could continue his journey till the end of 12th day.
- **Neuro-Principle: Loss Aversion**—as we know people are more than twice sensitive to loss rather than win winning, applying the same concept customers are more inspired to prevent a losing streak they've built than to start a new one. Thus this will help in preventing the skipping of saving days.

- **Personalized Challenges:**

- **Concept:** "Your AC can turn out to be your biggest energy user. If you can decrease its usage by 60 minutes and be ready for **the Reward of 50 Bonus Points!**"
- **Neuro-Principle:** Goal-Gradient Effect. As the customer gets closer to Finishing line, they tend to fasten up

their efforts. So this makes challenges being felt as more personalised and achievable.

Feature 3: Pitching the right tab- the community, utilising the Social Proof

Social Proof—our look out to others' behaviour to guide our own in ambiguous situations. It makes energy preservation a focussed, normative behaviour rather than a isolated one.

When the task is done by the group the people left by the group also joins the group to impersonate the same activity as that of the group. Each individual in a group feels connected and tries to achieve the goal of the group, thus it makes the target an ambitious one and makes energy preservation a more focussed approach.

Strengths of this Design:

- **Positive Framing:** Instead of putting shame, usage of positive encouragement is used to make others get motivation ,say the person doing the job may be called as "Green Leader" which encourages others to take the similar task in hand.
- **Collective Efficacy:** In order to make something bigger the "Community Goal" is set for enhancing commitment.
- **Healthy Competition:** Its all about preserving privacy & data security.

Enhanced & Additional Ideas:

- **Collaborative "Energy Boss" Events:**
- **Why it Works:** This strategy works

because it makes the one feels associated with the team together and as being a part of the team, individual progress is checked with the group's progress. This sense of psychology motivates people to do social group actions (social proof). So basically, in **group dynamics** and social proof psychologies help in achieving the target as a whole.

For example : Saying “you should make the your trash clean” vs the the campaign like “ India vs Trash & garbage.”

• Normative Comparisons with Context:

To be a part of the team is a natural desire. This "all-hands-on-deck" challenge turns energy saving into a shared mission, uniting us against the summer heat.

• "Neighbourhood Kudos" Feature:

Neighbourhood Kudos :- Positive reinforcement is very important as it motivates the individual to continue work in a given direction based on his appreciated efforts. Hence if in community a system like an act of appreciation can be recorded for the pupil who help others or create something wonderful for the society can be given '**kudos**' points. These points can be given to every individual who was seen helping others ,by the person who got a help. This will make community a healthy and happier place, where through gamification of getting good points or '**kudos**' individual is motivated to behave in a good way and this also keeps **the community spirit** very high.

The core idea is celebrating the everyday

heroes in the neighbourhood, rather than focussing on the problems of the community.

Proposing a New, Integrated Feature

Feature 4: Using the important psychological parameters like Cognitive Ease & the IKEA Effect and using the The "Smart Home Hero" Narrative & Automation, that can really help in achieving the objective.

- **Traditional:** Where devices are bound to strict time schedule and does not give any type of commands to its users.
- **Neuro-Informed:** When the normal activity of automation turns into more relatable activity by association of emotions into it ,leads to neuro informed decision taking which has a greater impact on the individual.

How it works:

- **The "Hero's Journey":** Creating a user experience in a way ,so that by his action he turns out to be a saviour or 'Hero' of the place of his stay. For example using an motivating and emotional story to let the person know after effects of his actions like: "A peak energy event is coming! This is a threat to the grid and your wallet. Let's prepare your house to face this challenge automatically."
- **Customizable "Battle Plans":** Instead of a normal "peak time setting," the user creates or customizes a "Cooling Battle Plan" or "Quiet Mode." They choose which devices to adjust and by how much (e.g., "Set thermostat to

78°F, delay dishwasher by 2 hours").

- **The "IKEA Effect" in Action:** Because the user had a hand in creating the plan, they value it more highly and are more likely to trust and stick with it.
- **Post-Event Debrief:** After the automation continues, provide a summary: "Your Battle Plan was a success! You saved 2.5 kWh and earned 34 points. Your home is a Peak disruptor!" This closes the loop, providing cognitive closure and reinforcing the positive behaviour.

Feature 4: The "Smart Home Hero" Narrative Leveraging Cognitive Ease & the IKEA Effect

- **Conventional Approach:** Manual control or regimented and less flexible, while pre-set timelines for smart devices, which can feel impersonal and restrictive.
- **Neuro-Informed Approach:** T Turning participation from passive to active activity through a collaborative journey. This narrative framework fosters a sense of user ownership creates energy-saving actions feel engaging and empowering.

How It Works:

- **Frame the Narrative: "Your Home as the Hero."** The system introduces automation events as a compelling story. Instead of a dry alert, the user receives a mission briefing: "A peak energy event is approaching—a threat to the grid and your wallet. Let's prepare your home to face this challenge automatically." Tis frames

the consumer to get converted from passive viewer to active commander.

- **Co-Create a robust "Execution Plans."** Replace technical terms like "settings" with thematic "Execution / Action Plans" (e.g., "Peak Power Plan" or "Stealth Mode"). The user doesn't just configure settings; they crop their strategy by determining devices to adjust and by how much (e.g., "Pre-cool to 72°F now, then set to 78°F during the event" or "Delay dishwasher cycle by 2 hours"). This collaborative creation is key.
- **SPIKE the "IKEA Effect."** Rather than keeping the user sit on the corner of the whole process, letting them involve in creating or simply assembling a final product gives him sense of more appreciated and more involvement gives emotional attachment with the product.
- **Execute a "Mission Recap."** After the event, the system provides a clear, rewarding summary: "Mission Accomplished! Your 'Peak Power Plan' saved 2.5 kWh, reduced strain on the grid, and earned you 34 rewards points. User Residence is a peak disruptor!" This insight provides gratification to the cognitive decision and it also reinforces the positive behaviour after getting the positive response from the customer, and the loop gets completed which finally gives emotional satisfaction .

DISCUSSION

Paradigm Shift: A journey starting from Information and leading to Integration

The proposed framework indicates a paradigm shift as they do not simply

use digital tools for ease of work, but involve the consumers in the process as well as usage of interfaces like dashboards helps them get instant gratification. They are translated from actionable dashboards of information into integrated, dynamic catalyst of change that work in sync with human psychology. This critical insight that the "sustainability gap" is not merely a complex technical issue but a human-system problem, that address both human cognitive and behavioural components.

Ethical Considerations and the Risk of Manipulation

The innate ability to influence behaviour through multiple subconscious channels asserts ethical responsibility. This framework must be firmly grounded in the principles of libertarian paternalism & prosocial nudging (Thaler & Sunstein, 2008). We propose three core ethical pillars:

- **Accountability with Transparency:** Users must be able to comprehend how the system operates, including the principles it employs. This could involve a "Why did I see this?" feature that explains a nudge's purpose and offers options to opt out of specific elements like gamification or social comparisons.
- **Alignment to beneficiary:** The primary objective must be the legitimate welfare of the user and the overall good. The design must circumvent "greenwashing" and must never manipulate users into decisions that are against their own best interests (e.g., sacrificing comfort to an unhealthy degree).
- **Sustenance of Autonomy:** Nudges is

psychological and brain triggering signal, which uses the simple action through which the cognitive empowering user makes choices which are aligned with their long-term values (e.g., saving money, protecting the environment). It is obvious that the final decision must always rest with the user, but the activity is generally chosen as it connects more logically with the Prefrontal cortex of the user.

Set Limit and Reflection:

This approach is not a universal solution. Its effectiveness is contingent upon several critical factors:

- **The New Digital Divide:** Banking on sophisticated applications risks excluding older, low-income, or digitally uneducated gross populations, which works as a catalyst in widening a "sustainability privilege gap." Supplementing low-tech solutions and inclusive design are therefore essential.
- **Cross-Cultural Variability:** Prejudices at the Cognitive level are not uniform across cultures. The power of Social Proof may be strong in closed communities and gross societies, while game theory 2 focused on individual achievement results in more in individualistic cultures. Dynamics at rural and cultural sensitivity are compulsory to a large extent.
- **Pleasant / Unpleasant Adaptation & Nudge Fatigue:** When the same type of nudges and rewards keep on repeating, it makes users not interested after a span of time. Hence it is required to regularly change the

challenges, feedback and the way motivation rewards point are given. Thus a strategic transition from external rewards to fostering internal motivation needs to be refurbished again and again with the best of ideas.

- **Technical Constraints as Ultimate Limits:** No digital nudge can take a place of lack of infrastructure or counterproductive policy. So even if the best tools are available it will not be of much help if the underlying structure does not support it, even the most sophisticated app will fail. Digital tools must be part of a broader, systemic solution.

The Next Euphoria: Hyper-Personalization & Generative AI

Generative AI can help in creating a different and personalised messages every time, so the engagement with user is most of the time a new experience. An AI-powered system could:

- **Dynamic, Personalized Content:** Instead of Simplifying and augment messages, an AI could create unique, context-aware feedback (e.g., "You saved enough money during yesterday's travel by giving a joy ride to your neighbours on your EV for 20 miles!").
- **Nudge Strategies in Real-Time:** If a user shows signs of restlessness and fatigue with a points system, the AI could effortlessly shift its strategic paradigm to mention social proof or environmental impact metrics customised to that user's consumer behaviour pattern.
- **Facilitate a Natural Language "Coach":** Both Active and Passive

Communication can happen to understand habits ("Why was my energy use high last Tuesday?") and receive personalized, actionable advice, thereby enhancing both transparency and efficacy.

Avenues for Future Research

This framework opens several critical pathways for further investigation:

- **Large-Scale Field Experiments:** Experimenting longitudinal Randomized Controlled Trials (RCTs) across various domains (e.g., energy, waste, transport) , as a result of this finding the quantitative measures ti it which will help in measuring a long term effect and checking how neuro-informed designs affect the real-world behaviour.
- **Cross-Cultural Neuro-Economics:** Critical analysis to specify how cultural paradigms modulates the efficacy of vivid nudges (e.g., loss-aversion vs. gain-framed messaging) using both classical behavioural and neuroscientific data.
- **Synergy with Policy:** Multi-level interjections & interventions. Are prerequisite in order to discover how neuro-informed digital tools can be intertwined with conventional matter of policy instruments (e.g., carbon pricing, rebates) to create synergistic.
- **AI-Personalized Nudging:** Creating a effective and strong evaluation of **creating** an adaptive behaviour-change system that evolves with the user.
- Developing and AI testing machine Working models that will humanize

the type, timing, and intensity of nudges,

Conclusion

The pursuit toward self-reliant and sustainability and net-zero cannot be achieved by forces of technology only. The incorporation of behavioural science is of supreme significance. Insights from behavioural neuroscience and neuroeconomics provide the code for this software. Metaphorically, then the behavioural component is the critical *software* that drives its operation

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