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Adoption of Green Technology: Insights from Indian Telecom Service Providers

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The telecom industry is a key driver of operational efficacy across societal and economic domains. Within the telecom industry, mobile technology is growing fastest. The increasing number of mobile subscribers supported by correspondingly large number of mobile towers is creating a massive impact on the environment by substantially raising the greenhouse gas emissions, which are expected to rise with the integration of network components aimed at improving efficiency in next generation technologies. Hence, adoption of green technologies in the telecom industry is the need of the day. Research in green telecom adoption is rather limited, particularly in the context of emerging economies such as India. However, interestingly, India presents an interesting case to study as it is the world's second-largest telecom market with over one billion subscribers. Therefore, this study is taken up, which identifies the factors of green technology adoption by telecom service providers in India. First, open-ended semi-structured interviews were conducted with 10 telecom experts in India. The analysis was done using content analysis. The findings reveal 10 factors and 24 subfactors of green technology adoption. Further, by development of causal-loop diagram, the study identifies 30 interrelationships among subfactors, thereby offering a holistic perspective aiding in informed investment decision towards implementing green telecom technology. This study's main contribution lies in proposing the interrelationships among factors for increasing the green technology adoption.

Keywords: Causal loop diagram, Content analysis, Green technology adoption, Green telecom technology, Telecom firms

Introduction

In the recent years, it is observed that improving environmental practices in the organizations has taken priority and is the main concern among different stakeholders such as policy makers, firm managers, and consumers.[1] In the context of rising green awareness, policymakers are driving regulatory frameworks and incentives, firm managers are responsible for aligning business operations with green goals while balancing costs, efficiency and competitiveness, while consumers are becoming increasingly aware of environmental issues and are beginning to expect eco-friendly practices from service providers. Despite widespread good intentions to decrease global energy consumption, it continues to trend upwards. The Information and Communication Technology (ICT) sector contributed to 4% Greenhouse Gas Emissions (GHGEs) in 2024, which is forecasted to rise to 14% in 2040.[2] ICT serves as the broad domain that encompasses various digital and communication technologies. Within this hierarchy, Telecommunication (telecom) technologies constitute a foundational layer, while mobile technologies represent a dynamic subset focused on wireless connectivity and mobility. Hence, the concept of green technology adoption has been envisaged, focusing on sustainable practices in ICT by reducing e-waste and using green energy for data centres and telecom towers.[3] In this research, green technology adoption is defined as the process by which firms begin to accept, implement, use and integrate environmentally friendly technologies into their practices and operations.

Despite being part of the broader ICT ecosystem, telecom industryalone is responsible for 1.6% of global CO_2 emissions.[2] Telecom firms have several options to reduce GHGEs, such as by electrifying their vehicle fleets, implementing 5G energy-saving features, and phasing out copper networks & 3G infrastructure. However, the bigger challenge lies in reducing indirect emissions across the entire value chain, as they involve suppliers, customers, and partners throughout the production, distribution, and use of products and services.[4] Exercising such options leads to Green Telecom defined as reduction of GHGEs produced both directly and indirectly by telecom firms.[5]

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Previous studies have focused broadly on green technology adoption in ICT sector.[6-9] Green ICT is a broader concept encompassing data centres, smart technologies, cloud computing and many more while green telecom is a subset of green ICT focusing on core sustainable telecom operations like optimising mobile towers, energy efficiency in base stations, etc. The researchers have attempted to understand the green technology adoption phenomena by synthesizing relevant literature[10] and identifying the factors. Numerous factors may influence an organization's decision to transition to green.[11,12] However, integrated approaches that consider how different factors reinforce or constrain each other on the ground-level has not been studied. This indicates that there have been limited efforts looking green technology adoption from holistic perspective especially in telecom firms.

A report by Statista (2023) provides insights into global preparedness for adopting green technology. The report highlights that the five most preparedness countries to adopt and adapt green technologies are the developed nations. Developing countries are lagging with respect to green technology due to several challenges like financial access, research & development and skills & education. Further, among BRICS countries, Brazil ranked on 40th place, India on 46th and South Africa on 56th for green technology shift.[13] Hence, this study focuses on green technology adoption in telecom firms in the context of emerging economies, with a specific focus on India.

Also, India presents an interesting case as i) India is the second largest telecom market worldwide, with 1,197.23 million mobile subscribers[14], ii) 3G networks are still used in India where BSNL is one of thetop 3G provider with a market share of around 8%[15] and 3G shutdown is considered an important aspect in reducing carbon footprint of telecom sector[15], iii) telecom in India contributes 35 million tonnes of CO_2 Equivalent (CO_2e) annually, which is expected to triple with 5G rollout, though only two Telecom Service Providers (TSPs) have launched 5G so far[16], iv) green telecom adoption in India is progressing at a slow pace, as firms have yet to see Return on Investments (ROI) made in previous technologies, and the high upfront costs of solar panels put off further investment.[17,18]

Accordingly, this study seeks to examine the reasons behind the slow adoption of green telecom in India and to investigate the comprehensive impact of these influencing factors. Building on the above context, this research has two key Research Objectives (RO): -

RO1: To explore the factors of green technology adoption among TSPs in India

RO2: To establish interrelationships among the identified factors.

Technological Background

Introduction to Green Telecom in India

ICT sector has been moving steadily towards a low carbon economy.[2,16] Over the years the telecom sector has shown tremendous advancements moving from 2G to 5G.[17,19] During COVID 19 where other industries were facing challenges in financial performance, telecom experienced a growth.[20] Data usage has increased by 60% from 2020 to 2024 globally, indicating increased energy consumption and consequently carbon emissions.[2] The green telecom has been defined by Telecom Regulatory Authority of India (TRAI) as 'reduction of the GHGEs caused by the telecom industry.[5] Apart from environmental concerns green telecom also offers economic benefits by using energy efficient network and devices.[21,22] Technologists have started working towards green telecom worldwide where different dimensions of greening are focused such as energy efficient base stations and optimizing infrastructure.[2,23] The comparison of generations of mobile technologies from green perspective is shown in Table 1.

About 25% towers in India have access to power supply for less than 12 hours and they heavily rely on Diesel Generators (DGs) for backup.[24] These telecom towers in India account for approximately 60% of the country's total diesel consumption leading to GHGEs.[24] Due to environmental concerns rising due to DGs usage, Indian TSPs are now installing green telecom towers that consume 1/4th power compared to existing ones. Also, the major TSPs in India— Bharti Airtel, Reliance Jio and Vodafone Ideaare working towards greening their operations and services. For example- Airtel has set a target to be net zero by 2050.[25] Also, Reliance Jio installed photovoltaic systems at their 20,340 own tower sites, generating a total of 119,020 Megawatt-hour of green energy in 2023.[26] Telecom is a competitive industry, so firms often prioritize growing through network expansion and technology upgrades over renewable energy. Solar and hybrid systems are emerging, but this shift to adopt renewable energy is slower than expected in developing countries, mainly because firms are hesitant without immediate business

Table 1 — Comparison of various generations of telecom technologies from green perspective[21]

S. N.	Attributes*(units)*	3G	4G	5G
1	Carbon dioxide emissions *(metric tons)*	87 mt	175 mt	235 mt
2	Number of base station sites	3.4 million	7.5 million	11.5 million
3	Base stationdensity *(Base Stations per square kilometre*	5-6 BS/km^2	9-11 BS/km^2	50-60 BS/km^2
4	Average power consumption per site *(Kilowatts)*	1.7 kW	1.3 kW	1.1 kW
5	Green technology	High efficiency tracking	Greenbase station, phantom cells, liquid cells, soft cells	Massive Multiple Input Multiple Output, spectrum sharing
6	Carbon footprint per mobile subscription *(Kilograms)*	20 kgs	25 kgs	32 kgs
7	Radio access network electricity consumption*(terawatt-hours)*	48 TWh	78 TWh	87 TWh
8	No. of antennas at base stations	2	8	up to 100
9	Types of antennas	High gain and outdoor antennas	Patch and slot antennas	Phased array antennas
10	Operational Expenditure	Low	High	High

benefits.[13,27] Hence, it is critical for TSPs India to improve their capability for adopting, adapting and embracing green technologies.

Green ICT Adoption Models and Frameworks

Green technology refers to integrated sustainable solutions that balance economy, environment and society. However, there is still a lack of broadly established classification for green technology that often delays the development and usage of green technology among the value chain stakeholders.[27,28] Researchers have looked at adoption of green technology at different levels- country, firm and individual or end user. Elgin *et al.* (2022) measure green technology adoption at country level across globe, highlighting factors like economic development, regulatory frameworks, and technological capabilities.[29] They found that high income countries (such as Israel, New Zealand, Cyprus) tend to adopt green technologies faster, while developing countries (such as Sri Lanka, China, Bangladesh) stay behind due to financial and infrastructural challenges.[29] Jayaprakash & Pillai (2022) conducted a cross-country study and found economic (labour, capital and technology), social (human health, education and standard of living) and environment (CO_2 emissions, lifecycle assessment of Information Technology (IT) products) factors to be responsible for green ICT at country level, among which economic factor has the strongest influence.[30] They further discovered that in developed countries, ICT advancements positively influence environmental sustainability however, it has a negative influence in developing countries.[29,31]

Molla (2008) conducted his study on firm level to develop Green IT Adoption Model (GITAM) andidentified five key dimensions that influence adoption: economic, regulatory, ethical, technological and environmental.[11] Molla & Abareshi (2011) explored the factors motivating organizations to adopt Green IT using motivational theory. They identified four motivations among which eco-efficiency and eco-effectiveness were the most important drivers for adopting green IT. Further, they identified that the size or type of firms did not significantly affect these motivations.[32] Bose & Luo (2011) developed a model for assessing potential of firms for green IT adoption in Indonesia, and identified factors like— technological (sensory readiness, relationship readiness, synchronism readiness, identification and control readiness), organisational (firm size, champion support, resources), environmental (regulatory support, competitiveness).[31] A conceptual framework developed by Radu (2016) emphasizes factors like competitiveness, financial support, top managers, employees' skills, regulations, supply and demand influencefirm's green ICT adoption decision.[6] Hankel *et al.* (2019) explore the factors of green ICT adoption using maturing model, and identified strategic alignment, culture, leadership, government policies and technical infrastructure to be some important factors.[9] For sustainable telecom services in India, Chen *et al*. (2021) highlighted factors such as government policies, technological change, lack

of skills, customer expectation, market competition as the barriers towards green technology adoption.[10]

Dezdar (2017) conducted an individual-level study on green IT adoption among university students in Iran using an extended theory of planned behaviour. The study found that attitude, subjective norms, perceived behavioural control, openness, and future orientation influenced green IT usage intentions.[7] Anthony Jnr. *et al*. (2020) conducted study on perceptions of IT professionals and managers on green practices in Malaysian IT firms using Perceived Organizational e-Readiness Theory (POER) and Process-Virtualization-Theory (PVT). They found that POER factors (such as IT practitioners' awareness, IT governance, technologies and systems, IT strategy and information availability) influence perception towards green IT. Further, PVT factors (such as green creation, green sourcing, green usage, green distribution) are influenced by green practices.[27] Mouakket & Aboelmaged (2021) explored green IT adoption at individual and firm level in United Arab Emirates using technology-organization-environment framework and institutional theory. They identified that organizational factors such as resource commitment, management support, and quality of human resources significantly influence green IT adoption. Conversely, individual-level factors such as environmental concern and perceived usefulness have a weaker influence on green IT adoption decisions.[12]

Despite the literature available on green ICT and IT adoption, several important gaps persist. First, most existing frameworks and models are either conducted at the country level[29,30], individual level[7,12,27] or broadly addresses organizational drivers[9,11,32], thereby overlooking sector-specific adoption challenges. In particular, the telecom sector presents a unique context due to its high energy demand, complex infrastructure, regulatory policies, and essential role in enabling digital connectivity. Yet, firm-level studies focusing exclusively on telecom remain limited, with very few efforts made to understand how telecom firms perceive and respond to green adoption imperatives. While studies such as Chen *et al.* (2021) offer some insights on telecom sector, they focus on barriers rather than presenting a holistic approach.[10] These limitations indicate a clear need for a comprehensive, firm-level, and telecom-specific framework that integrates all essential adoption factors. Such a framework would not only bridge the contextual gap in the literature but also offer practical actionable insights for TSPs navigating the green transition.

Research Methodology

This study employs an exploratory-descriptive qualitative research design, appropriate to phenomena where decisions are shaped by interactions among various stakeholders considering the factors – both quantitative and qualitative. This approach is widely recognized effective for capturing the complexities and inter-relationships.[33] The qualitative study offers a deeper and comprehensive understanding of adopters' perspectives, by uncovering real-world ground-level insights from their experiences.

Data Collection

The open-ended semi-structured questionnaire was designed to gather all information from interviewees, while also allowing flexibility to ask questions. TSPs were chosen for interviews (with experts in the domain) because they are the largest contributors to carbon emissions within the telecom sector, primarily due to their extensive network infrastructure and high energy consumption.[2] Their commitment to successfully adopt green technologies plays a vital role in shaping the sector's sustainability efforts. A total of 15 experts were contacted, 10 agreed to participate in the study. The details of respondents are presented in Table 2. Each interview lasted around 40 to 45 minutes. To maintain confidentiality, firm name and respondent identity is not disclosed. Interviews were transcribed immediately after it ended and analysed using content analysis.[34,35]

Data Analysis

Data analysis was done using content analysis approach. Content analysis was adopted as it allows for a deeper and more comprehensive understanding of the phenomenon.[34,36] This method was used to review the transcripts and validate the factors discussed in the literature, as well as to explore their interrelationships. The analysis was conducted in two phases: first phase involved analysing the interview data through coding process. This involves gathering information from participants' perceptions, grouping beliefs that reflect similar concepts, and organizing concepts that relate to common constructs. In the second phase, after identifying concepts and related constructs, the transcripts were re-analysed to explore if any relationships exist between the identified factors and established their interrelationships.[33] A sample of the data analysis is shown in Table 3.

Table 2 — List of interview respondents (telecom experts)

Expert	Designation	Firm	Experience (in years)
E1	General manager	F1	10+
E2	Format lead	F2	15+
E3	Senior manager	F1	15+
E4	Technical head	F3	10+
E5	Manager	F2	20+
E6	Project manager	F4	15+
E7	Deputy general manager- environmental, social, and governance (ESG)	F1	15+
E8	Head of planning	F3	10+
E9	Head infrastructure management	F2	15+
E10	Lead 5G deployment	F1	10+

Note: F1, F2, F3, F4– presents telecom service providers (TSPs) in India

Table 3 — Sample of data analysis

Questions	Transcripts	Factors	Relationships
What are the environmental concerns currently influencing telecom operations in India?	"Diesel generators run for at least 8-10 hours daily in many regions. That's a huge concern, not only in terms of emissions but also huge operational expenditure" "Green technology is expensive, as not all vendors offer green equipment. Even if we want to go green, we face difficulty in finding quality vendors"	Operational expenditure (OPEX) (E3-E6, E9) Expensive (green technology cost) (E1-E3, P7, E10) Limited green vendors (E3, E5, E10)	Diesel generators High OPEX Limited green vendors Green tech cost Limited green vendors Adoption
What are the barriers your organization faces when adopting or implementing green technologies?	"Cost is the biggest barrier to go for green technologies. Installing solar panels or switching to hybrid power solutions requires huge initial investment, and we're not sure about the return or payback period." "Lack of skilled workforce is also a concern."	Cost (E1-E3, P7, E10) Long and uncertain payback period (E1, E4, E5) Huge initial investment (E1-E4, E6, E9) Lack of skilled workforce (E3-E5, E10)	Huge initial investment Cost Installing solar panel Cost Adoption Cost Long and uncertain payback period Lack of skilled workforce Adoption
How prepared do you think your organization is for adopting green technologies?	"There's no dedicated strategy for green technology adoption. The top management is yet to prioritize this as a goal" "We don't have staff trained in managing hybrid power systems or solar panels. We would need external partners which needs another investment"	Strategy (E2, E6) Top management (E2-E6, E9) Skilled workforce (E2, E4, E7, E10) External partners (E1, E8)	Top management Strategy Strategy Adoption Skilled workforce Cost Skilled workforce Adoption External partners Cost

Findings and Discussion

Factors and Subfactors Influencing Green Technology Adoption

For the first objective, the content analysis revealed 10 constructs (factors) under 4 categories— technological, financial, organizational and environmental, and 24 concepts (subfactors) as shown in Fig. 1. Two new factors have been identified, namely, sustainable technology upgradation and integration risk. Further, 7 unique subfactors were identified— cost savings through optimisation, process digitalization, operational agility (under factor relative advantage), compatibility with legacy systems, dependency on limited technology vendors (under integration risk), licensing cost, and cost of retrofitting legacy systems (green technology cost).

Technological:

Relative Advantage is the degree to which green technology is perceived better than the traditional infrastructure. With respect to green technology, the existing infrastructure and processes will be advanced through digitalization using technologies like Artificial Intelligence (AI), Internet of Things (IoT) for predictive maintenance and energy optimisation leading to cost reduction and agility in operations. Interviewee (P5) said: *"one of the biggest changes we've seen since moving to an AI platform is how it uses real-time data to cut down energy cost". By*

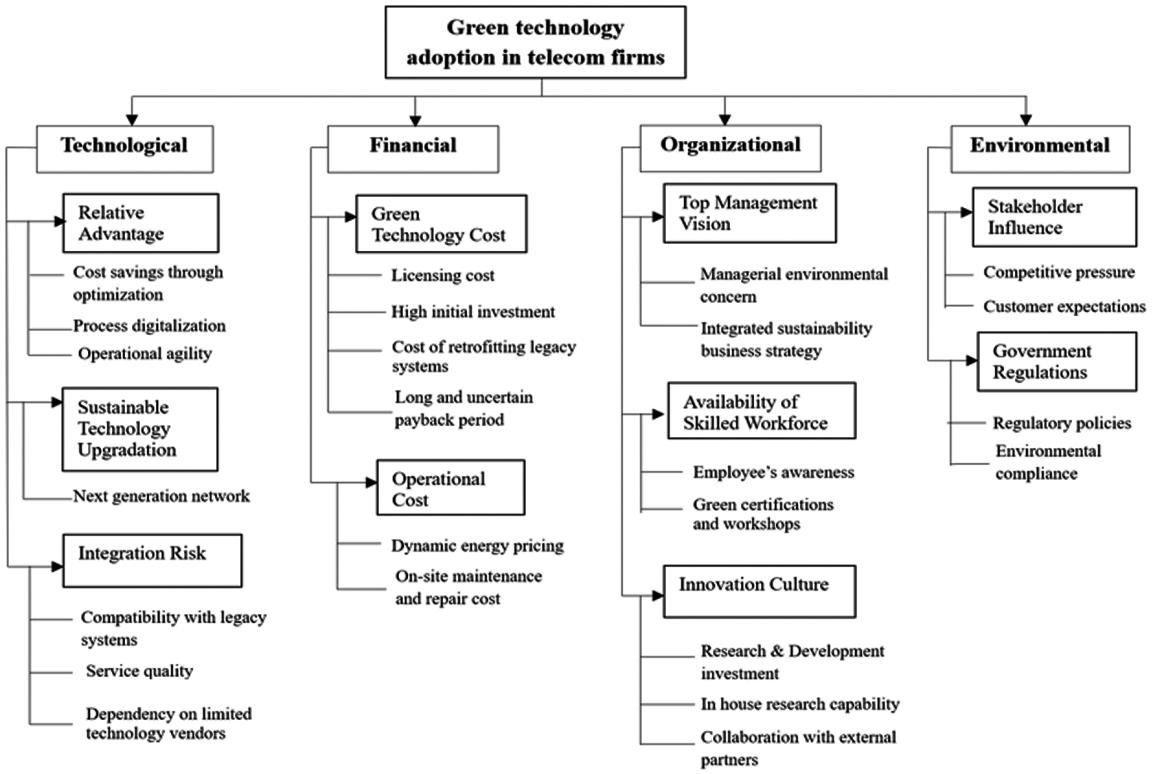

Fig. 1 — Factors and subfactors of green technology adoption

using AI we can adjust lighting and cooling system based on real time usage pattern, earlier we used to rely on fixed schedules."

Further, integration risks were found to be one of the barriers towards adopting green technology by TSPs. Interviewee (P3) highlighted: *"the biggest challenge is compatibility with existing systems. Most telecom infrastructure is not built for renewable energy sources or energy-efficient hardware, so integrating it often comes with high costs and technical complications."* Also, sustainable technology upgradation emerged as a unique factor while exploring how TSPs in India are navigating the transition toward next-generation networks. Deep intertwining of hardware, software, and network elements in the next generation technologies makes the telecom system more complex and vulnerable. With the arrival of 5G in India, there is increasing pressure on TSPs to upgrade their infrastructure. However, what differentiates sustainable upgradation is the deliberate effort to integrate environmental considerations into that process. The challenge is intensified by the coexistence of legacy infrastructure alongside new deployments. Hardware compatibility of digital and physical system is critical, older systems may not efficiently support energy-efficient technologies. When AI-powered energy systems are installed, it can misread some data from old equipment as they are not compatible and shut down cooling too early at some places. This can lead to degraded *service quality* and customer dissatisfaction. In a competitive telecom market, service quality becomes a key differentiator for TSPs to retain and expand their customer base. The renewable sources of energy such as solar, wind, biomass presents variability in energy supply compromising in network uptime and service quality, especially in rural sites which still presents a huge potential in India. This fears TSPs in India to switch from proven energy sources to other greener substitutes.

In addition, the limited availability of green technology suppliers/vendors presents restriction to TSPs' flexibility and forceful adaptation to vendors technology limitations. When there are few suppliers, price competition is less which leads to higher costs of green technology. Also, it becomes difficult for the existing vendors to meet the demand by TSPs which slows down the pace of adoption. Expert (P8) highlighted: *"right now, there are not many established green technology suppliers, specifically in*

telecom which creates a kind of vendor lock-in and limits flexibility as well as bargaining power." This presents hesitation towards adopting green technology. Our findings align with the study of Chen *et al.* (2021), which identify rapid technological changes and lack of infrastructure as a barrier in sustainable telecom services.[10]

Financial:

Green technology cost refers to the total expenditure required to adopt and adapt sustainable technologies. In the telecom sector, adopting green technology can be strategically valuable (e.g., for corporate social responsibility, long-term profitability or regulatory compliance), but it has short-term financial challenges like high licensing cost, huge upfront costs and delayed ROI. Green technology usually requires digital platforms (cloud, AI) which has high *licensing or outsourcing cost*. Further, replacing DGs with solar or using hybrid systems requires *high initial capital expenditure* in buying *new ones or retrofits*. These technologies offer cost savings in long run, but the *return period is uncertain.* Interviewee (P2) highlighted: *"it is a long-term investment, emissions are reduced, government regulations are followed, and also financial savings will happen, just not in one year, it will take some time."*

In addition, *dynamic energy pricing* acts as an enabler towards adoption decision where electricity pricing fluctuate based on supply, demand, and market conditions. This motivates TSPs to adopt renewable energy sources to reduce their operational expenditure for faster payback and maintain competitive pricing for customers. While these renewable sources prevent unforeseen operational costs, they require *additional maintenance cost* which is a trade-off. Green technology requires specialized maintenance skills, which can increase operational costs to have expert service. Interviewee (P6) said: *"green technology does offer long-term savings, but maintenance is not always straight forward, the need for specialized parts or technicians ends up increasing the overall operating costs."* This creates hesitation in companies to adopt green technology as many of them may not be financially stable and ready. The findings are in line with Molla (2008), who identify economic as a key dimension of green IT adoption.[11]

Organizational:

Organization factors refer to internal preparedness of a firm to adopt green technology. Strong vision and support from *top management* is critical to prioritize sustainability goals as they are the decision-makers. Leaders set the vision and motivate their teams to accept the change. Managers today are aware of the sustainability visions and *concerned to meet regulatory requirements* and customer expectations. This concern motivates them *strategizing the sustainability goals* to integrate them with business. One interviewee (P7) said: *"we believe it is important for the environment and our business to adopt green technology. Our senior management is talking about greening, but it is still not the priority in their business strategy."* However, a recent study by Mouakket & Aboelmaged (2021) reported weak effect of environmental concern on green IT adoption, in contrast we found that managerial environmental concern has a strong effect on green technology adoption in telecom.[12]

Further, successful adoption requires not just top leadership vision, but also a *skilled workforce* to execute that vision effectively. One of the interviewees (P1) said: "*even if we change the existing technologies, we do not have the experts who know how to operate and maintain new green technologies and adapt to the change." Training programs and workshops* are essential to generate awareness and skills in employees and keep them updated. A skilled workforce adapts more easily to new processes and helps overcome resistance to change. Moreover, *in-house Research & Development (R&D)* enables the adoption process. *Innovation culture* is an environment within a firm that encourages employees to think creatively and propose new ideas as well as execute through R&D and by *collaborating not only within the firm but also with external research* units. Firms can continuously improve and stay at the forefront of green innovations by developing innovation culture. The findings are in line with Chen *et al.* (2021), who identified lack of education and technical skills to be a barrier in green telecom services.[10]

Environmental:

Environmental factors refer to the external factors that enables or hinders green technology adoption. *Government laws and regulations* set compulsory standards for emissions, and waste management for firms, meanwhile subsidies and tariffs help to lower the cost of adoption. Interviewee (P9) said: *"government set the standard that we have to comply, but we also take advantage of subsidies and tax benefits provided by government when upgrading to new technologies."* It is important that all key partners in the current telecom ecosystem be aware and

involved in sustainability processes, as the telecom value chain has become complex influencing decision-making.[10] For example— a telecom operator can only use green technologies if network manufacturers will produce it and there are multiple green vendors to provide it. Also, customer should be willing to pay for these technologies and create demand for them.

Industrial users must meet some government standards, so they demand for green technologies, but end users are not bound by any regulations. Interviewee (P10) highlighted: *"honestly, customers are only bothered about service quality and cost, sustainability is an additional advantage but only if they are not asked to pay extra for it."* Our findings are in line with the study of Chen *et al.* (2021) and Hankel *et al.* (2019), who identified government support and change of customer expectations to influence green technology adoption in ICT sector.[9,10]

Interrelationships Among the Subfactors

Further, to achieve the second objective, we explored the relationships between the identified sub-factors. CLD (Vensim 10.3.2) was used to illustrate the interrelationships among subfactors. Thirty (30) relationships were discovered as shown in Fig. 2. Eight (8) direct relationships were identified between the subfactors and the decision to adopt green technology.

CLD illustrates how different parts of a system are connected and influence each other. Each causal connection is marked with a "+" or "–" sign to indicate its effect. A "+" means the change moves in the same direction, and a "–" means it moves in the opposite direction. Loops are called positive or negative depending on the overall interaction and influence of the variables within the loop.[32] Factors like dynamic energy pricing, on-site maintenance and repair cost, payback period, licensing cost and high initial investment inversely influences green technology adoption. For instance, balancing loop depicts the relationship among green tech compatibility with legacy systems, cost of retrofitting legacy systems, high initial investment and decision to adopt green technology. Here, cost of retrofitting legacy systems is increasing initial investment which is causing inverse impact on adoption. When green technologies such energy-efficient base stations, smart cooling systems, cloud computing are integrated with existing systems or networks, the complexity increases. This complexity is due to the compatibility issue of legacy systems with latest technologies. Specialized skills are required and trained workforce is needed to retrofit and further maintain green technologies which increases the overall costs making the transition to green technology financially unviable, especially for TSPs in emerging economies.

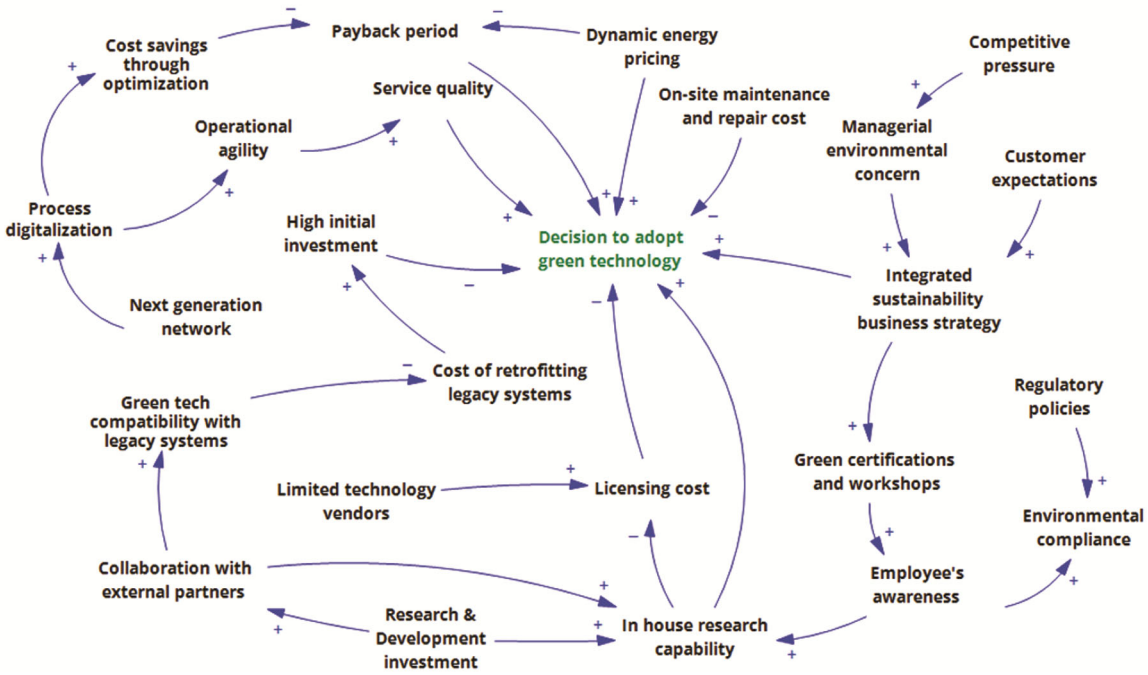

Fig. 2 — Causal loop diagram (subfactor level)

Similarly, for example one of the reinforcing loops depicts the relationship among integrated sustainability business strategy, green certifications and workshops, employee's awareness, in-house research capability and decision to adopt green technology. In this loop one factor strengthen the impact of another one, i.e., if one increases other increases or if one decreases other decreases. When a telecom company adopts a dedicated sustainability strategy, it sets the vision and standards. To execute this strategy firms, try to gain green certifications and train employees through workshops, thus creating awareness as well as skills among the employees. When employees are aware, motivated and skilled, they are more likely to contribute ideas and support in-house research activities towards sustainability development. This in-house research capability enhances the confidence to make informed decisions to adopt green technologies. Hence, the reinforcing loops enable the speed of green technology adoption by creating a positive feedback loop.

Conclusions

This paper explores green technology adoption by telecom firms in India, identifying 10 factors and 24 subfactors, including two unique factors—sustainable technology upgradation and integration risk and seven unique subfactors as critical insights. The CLD model highlights key barriers such as high adoption costs, infrastructure upgrades, legacy system compatibility, and skill gaps. Extending prior work, this study draws on field data from telecom experts to uncover real adoption challenges and propose a structured decision-making framework. To advance adoption, telecom managers should align sustainability goals with business objectives, invest in in-house R&D, and build collaborations for internal engagement and external support. Policymakers should create standardized sustainability guidelines tailored to telecoms, including carbon benchmarks, e-waste regulations, R&D grants, and tax benefits. Policies encouraging vendor participation, especially startups, through reduced entry barriers and simplified regulations can enhance affordability and access. Future research should expand to other developing countries and enable quantitative validation.

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