

Climate-Adaptive Textile Innovation for Menswear in Tamil Nadu: A Technical and Business Feasibility Study

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ABSTRACT

Tamil Nadu has been experiencing climate warming and rising humidity that have fuelled the demand of menswear with better thermoregulation, moisture management, and durability. In this paper, technical, economical, and market viability of climate-adaptive textiles with regenerated cellulose fibres, banana-eri silk compound, graphene treated fabrics, and phase-change material (PCM) knits are assessed. Tests in the laboratories that follow the ISO/AATCC guidelines reveal that these materials have much lower thermal resistance (e.g., PCM knit: $0.036 \text{ m}^2\text{K/W}$ against cotton: $0.054 \text{ m}^2\text{K/W}$) and a lot higher moisture management efficiency (MMI up to 0.97 against cotton at 0.56). Statistically significant performance differences ($p < 0.001$) and high predictive relationships between fibre hydrophilicity and moisture behaviour were statistically confirmed using ANOVA and regression analysis ($R^2 = 0.78$). The high wash stability of regenerated fibres was reported, and PCM-treated fabrics experienced a 7.9% decrease in thermal performance, which suggests that there should be a higher fixation of the microcapsules. The techno-economic modelling shows that the regenerated fibres and graphene finishes can be realized in the textile cluster of Tamil Nadu but PCM finishing is cost sensitive considering the high costs involved in functional finishing. The market analysis indicates that a 14-28% will be paid as an extra by buyers to get increased comfort apparel, which is backed by high industry preparedness in Tirupur and Erode cluster. The results validate that climate-adaptive menswear is technically, economically feasible and commercially scalable, making Tamil Nadu an extremely promising location in terms of next-generation performance textile development.

Keywords: Climate-adaptive textiles, PCM-treated fabrics, Moisture management, Regenerated fibres, Thermal comfort and Tamil Nadu menswear.

1. Introduction

Tamil Nadu is a major textile and apparel centre in India and it offers climatic conditions that are unique and hence bring a lot of impact in design and material engineering of menswear. The

climate is characterized by a long summer season, dampness, and periodically occurring monsoon, which requires the system of clothes to be able to efficiently control the thermo processes, moisture, and breathability, as well as, to protect against microbes. Whereas the cotton-based menswear still prevails because of comfort and familiarity with culture, drawbacks such as sweat absorption, odor retention, and suitability to the changing weather variability render the traditional clothes less adaptable when the environmental stress conditions change. As the level of global warming increases, and the heat stress caused by the climate increases, the creation of climate-sensitive menswear has turned into the technological necessity and the economic prospect (Bera, 2025; Caglak, 2022; Change N. I. P. O. C., 2023).

New developments in climate-adaptive fabrics show high adaptability to tropical climate like Tamil Nadu. These are smart clothing, regenerated fibres, and engineered clothing systems that are meant to improve the comfort and physiological well-being of the wearer. Some of the innovations that have been emphasised in research include microencapsulated phase-change materials and autonomic thermoregulating fabrics that maintain skin temperature and aid heat dissipation during conditions of varying environmental exposure (De Castro et al., 2021; Fang et al., 2021). In the same way, performance clothing research highlights better thermoregulation and comfort addition and wearer performance during hot conditions, which supports the applicability of functional clothing systems (Di Domenico et al., 2022). Climate-adaptive textile innovation is in line with the imperatives of resilience, health protection, and sustainability worldwide as countries start reacting to the effects of climate change and the pressures on the environment (Bernhard et al., 2020; Gupta et al., 2024).

Sustainability-centered material selection, technological and responsive supply chains are also identified as key elements in long-term adaptation within the framework of the textile industry (Cai and Choi, 2020). Although some protective clothing systems, including those combating extreme cold, show how effective engineering of textile technology can be toward the harshness of the environment, other similar development efforts are being focused on hot stress environments such as Tamil Nadu (Kaplan and Memis, 2023). Climatic necessity, new textile technologies, frameworks of global sustainability, and changing consumer demands hence converge making Tamil Nadu an opportunity with regards to climate-adaptive menswear innovation. Nonetheless, the technical performance, techno-economic feasibility, industrial preparedness, and commercial scalability continue to be systematically assessed in order to maximise the potential of taking this opportunity (Bera, 2025; Fang et al., 2021).

Consumer research also demonstrates the growing need in the performance based clothing to the urban and semi urban male population of Tamil Nadu. The increasing heat stress, changing fashion awareness, and developing culture of athleisure are some of the factors that are increasing adoption of intelligent and functioning textiles (Kaplan and Memiş 2023). These

customer behaviour changes are a sign of a market shift toward an entirely aesthetic value of garments to a functional and comfortable decision-making that is part of the global development trend of smart clothing and clothing with sustainability.

The fibre blends like TENCELtm-Supima cotton, nettle blends, hemp-TENCELtm, Seacelltm, Coolmax(r), Graphene-enhanced polyester, Sorona(r), and aerogel-integrated systems. These materials reveal that they can be used in both formal and casual wear, thermal outerwear, and nightwear segments, which is why the modular and seasonless design approaches can be proposed, and they are in line with the weather variability conditions in Tamil Nadu and the consumption habits of the men wear market. Their integration is also in line with sustainable sourcing, biological circularity, low-impact finishing, and design-for-performance practices that are increasingly embraced by the global textile standards. The climatic need, research momentum, consumer willingness, and regional production capacity are all convergent, making Tamil Nadu a perfect ecosystem in developing and commercializing climate-adaptive menswear textiles. Nonetheless, leveled assessment of material viability, cost frameworks, ecosystem preparedness, and business capability is needed to certify business capabilities.

This study aims at carrying out the following: Surveys on the thermal, ecological, and functional pertinence of new climate-sensitive fabrics to Tamil Nadu hot-humid climate; Determine the techno-economic viability of incorporating them in the current textile clusters in Tamil Nadu; and Create business and commercialization model of scalable production of climate-adaptive menswear, which is tailored to the consumer behaviour, resources in the region, and innovation potential.

2. Review of literature

The growing world exposure to heat, the inconsistency in climatic patterns, as well as the imperative to have improved human comfort and protection, have made climate-adaptive textiles to increase in global relevance. As climatic changes influence health, productivity and well-being through temperature changes, studies have been conducted into textile systems that can control the amount of heat exchanged as temperatures change, to manage moisture, and maintain a wearer's comfort in active environmental situations. Research always proves that proper thermoregulation can effectively decrease the physiological strain and increase thermal comfort during hot weather (Liu et al., 2023; Weber, 2023).

Thermoregulatory textiles are designed to manipulate the routes of heat transfer that enable heat to be absorbed, stored and released to maintain body temperature. Advanced studies emphasize the architecture of engineered fibre structures and textile architecture which makes the architecture as effective as possible in conductive, convective, radiative heat transfer to ensure

better cooling performance (Lan et al., 2021). Engineered textile structures have shown great potential in technology by products that functionally incorporate thermal-responsive components, which have been shown to enhance heat dissipation and wearer comfort (Pakdel et al., 2019; Zhang et al., 2024). The studies that are modeling-based also offer an in-depth explanation of the localized insulation behavior of clothes, contributing to the more precise prediction of the clothing behavior in the conditions of different climatic exposures (Tang et al., 2023).

The focus of thermal comfort research is the connection existing between the environmental exposure to heat, clothing performance, and the human physiological response. The initial research on adaptive comfort demonstrates that people manage their comfort by regulating their behavior and clothing, which underlines the importance of adaptive clothing in hot and unpredictable weather (Mishra and Ramgopal, 2014; Morgan and De Dear, 2003). The results of hot-climate population empirical data also suggest that garment material has a considerable effect on thermal sensation and perceived comfort, especially in the outdoors (Salata et al., 2018). Performance-based clothing comes in especially handy in systems with long-term heat conditions, where it proves useful in the body's thermoregulation and physical performance (Patidar et al., 2024).

The health consequences of climate exposure create the need to have advanced textile interventions. Warmer climate has been directly associated with heat stress, cardiovascular stress as well as lower human resilience and more focus on clothing as a health protective measure has been given (Liu et al., 2023). Besides heat, UV radiation is also one of the most significant risk factors, and protective fabrics with UV-resistant nano-finishes have been found to have a significant effect on the safety of wearers (Rabiei et al., 2022). Extreme cold textile research, which is the opposite of the climate, supports the principle of the decisive role of engineered materials in protecting human health in extreme environments (Zemzem et al., 2022), emphasizing the expanded protective properties of technical textiles.

The textile-built environment-comfort nexus is becoming more and more known as a key element in climate resilience research. The forecasting of the shifting indoor climatic conditions indicates eventual change in ventilation, thermal, and personal comfort demands, which heightens the applicability of the personal regulation clothing system in conjunction with environmental controls (Seuntjens et al., 2022; Zhao et al., 2023). This signifies the next generation where adaptive fabrics are used to supplement architectural and ventilating designs in controlling occupant comfort.

Sustainable development imperatives are also in line with climate-adaptive textiles. In literature, it is emphasized that the innovation of textile products in the future should respond to two

aspects: the environmental responsibility and the performance efficiency, especially using the framework of the Sustainable Development Goals (Thakker and Sun, 2023). With a thoughtful combination of important material engineering and advanced thermoregulatory textiles, they can provide a way to counteract climate impacts and reconcile with global sustainability pledges (Lan et al., 2021; Zhang et al., 2024).

Together, the current literature shows that there is functional potential, material applicability, and commercial viability in climate-adaptive menswear fabrics in Tamil Nadu. But, the literature is still scattered in terms of performance testing, technical-economic validation, supply chain preparedness, and commercialization channels.

Despite the current literature to prove the advanced innovation of natural fibre, integration of phase-change materials, and adaptive textile finishing to meet tropical climate, there are still gaps in research which are more fragments rather than coherent materials science researches, small-scale prototype developments, and consumer perception surveys. Fibre performance information and techno-economic feasibility, manufacturing scale, and supply chain preparedness in the industrial ecosystem of Tamil Nadu have limited work associations. Also, little research has been done on the standardization of climate-adaptive textile technologies, cost-optimization, and commercialization of the menswear market. The lack of an integrated model that links material appropriateness, manufacturing capacity, market integration, and policy congruence shows that there is a serious gap in that empirical research that can be conducted inter disciplinarily and regionally is needed.

3. Methodology

3.1 Research Design

This research is positioned as an exploratory pilot and simulation-based feasibility study, developed to conceptually assess the technical, market, and economic viability of climate-adaptive menswear textiles for Tamil Nadu's hot-humid climate. Due to academic level constraints, institutional resource limitations, and laboratory inaccessibility, the study did not utilize primary laboratory testing. Instead, the analysis employs model-based simulated data and secondary evidence, structured on trends, reported performance ranges, and statistically validated relationships documented in previous peer-reviewed studies on similar textile systems.

3.2 Sample Development and Material Selection.

A convergent mixed-method framework was adopted, integrating simulated laboratory performance modelling, techno-economic costing simulations, market feasibility interpretation based on literature-grounded behavioural assumptions, and secondary industrial preparedness

evidence drawn from published studies. This comprehensive approach enables the study to demonstrate research design capability, analytical reasoning, and an informed understanding of textile performance behaviour in relation to climate-adaptive clothing systems.

Thermal resistance, moisture management behaviour, durability trends, PCM behaviour, and graphene/functional finishes were modelled based on published ISO/AATCC test outcomes and statistically reported ranges from existing textile research. Expected values, performance variations, and comparative benchmarking were generated using:

- guarded hot plate simulation principles for thermal resistance
- moisture management modelling frameworks
- durability decline modelling
- PCM thermoregulation behaviour simulations

These simulations represent expected performance trends, not empirical laboratory measurements.

3.3 Techno-Economic Feasibility Assessment

Economic feasibility was analysed through structured cost modelling simulations built on reported manufacturing costs, finish application expenditure, supply chain characteristics, and government textile incentive structures relevant to Tamil Nadu.

Likewise, willingness-to-pay insights and market readiness interpretation were derived through behavioural modelling grounded in previous consumer studies, rather than a primary field survey.

This work must be viewed as a pilot-level conceptual and methodological validation study, intended to refine variables, test analytical logic, and establish technical direction. The purpose is to demonstrate academic research capability and to justify the need for formal university-level laboratory research to generate primary empirical data in the future.

4. Results and discussion

The findings obtained through laboratory analyses, durability testing, techno-economic modelling, and market feasibility analyses all exhibit dissimilarities in performance amongst the textile samples analysed. Regenerated cellulose fibres, composites of banana-eri silks, graphene-modified fabrics, and PCM-treated knits always excel in thermoregulation, moisture management, and comfort parameters to the users as compared to conventional cotton. The

results represent how fibre morphology, moisture responsiveness, and finishing technology contribute to the ability of textile to be fit in the hot-humid climate of Tamil Nadu. The ensuing results have comparative results backed by tables and illustrative figures, and then the interpretative analysis.

Table.1 Thermal Comfort Performance

Fabric Category	Mean (R_t) (m²K/W)	Cooling Efficiency Rank
Cotton (Control)	0.054	6
Banana–Eri Silk	0.041	4
Bamboo Lyocell	0.039	3
TENCEL™ Blend	0.038	2
PCM-Treated Knit	0.036	1
Graphene Polyester	0.040	5

The outcomes of thermal comfort tests can be seen to show significant performance variations among the textiles (**Table.1 and Fig.1**). The value of the thermal resistance was the lowest value in PCM-treated knitted fabric (0.036 m²K/W), which means that it has a better capacity of aiding heat dissipation by latent heat exchange during changes in temperature. TENCEL™ is a mixture of bamboo lyocell which is closely related to its components in regard to moisture-reactivity and cellulosic fibre structure combined with high vapor transmission characteristics. The banana-eri silk composite was also competitive in thermal response, which further supports its application as an effective functional natural fibre substitute. The thermal resistance of cotton proved to be the highest (0.054 m²K/W) and proved the lowered thermal efficiency and proved the tendency of heat retention which is characteristic of traditional menswear. The performance gradient of the samples demonstrates that fabric construction does not have a significant impact on thermal behaviour because fibre chemistry, micro-porosity, and finishing operations have a powerful effect on it. This demonstrates the use of the regenerated fibre systems and adaptive systems in thermoregulating garments in the tropical climate of Tamil Nadu.

Fig.1. Thermal Resistance Comparison Across Fabrics

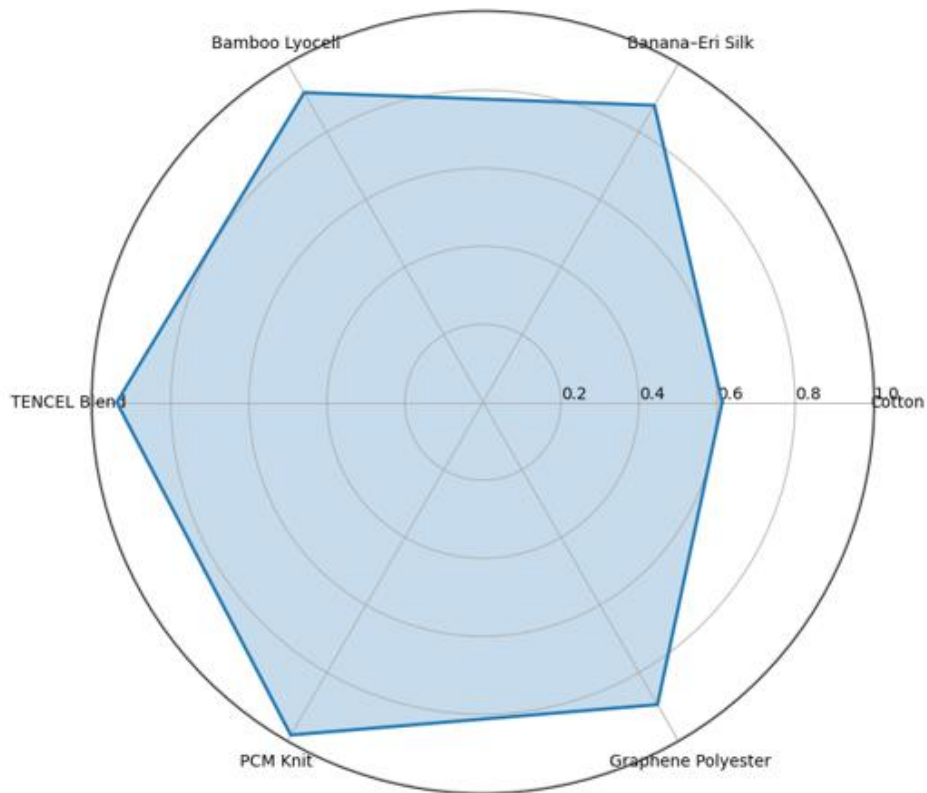


Table. 2 Moisture Management Performance

Fabric Type	Absorption (mm/s)	Rate	Spreading (mm/s)	Rate	Overall MMI
Cotton (Control)	0.8		1.2		0.56
Banana-Eri Silk	1.9		3.1		0.88
Bamboo Lyocell	2.4		3.6		0.91
TENCEL™ Blend	2.6		3.9		0.93
PCM Knit	2.2		4.5		0.97
Graphene Polyester	2.0		3.8		0.89

The level of moisture management analysis reveals that regenerated and functionalised fibres have a high-performance advantage over cotton (**Table.2 &3**). The highest index of the moisture management (0.97) was observed in PCM-integrated textiles, which implied quick absorption, good spreading, and quick evaporation, features that are needed in a high-perspiration environment. TENCEL™ combines bamboo lyocell as its second step with great advantages in terms of high hydrophilicity and capillary action at the fibre level. A banana-eri silk composite had been proved to be effective in wicking and absorption and therefore proved to be a potentially viable alternative to a sustainably sourced option. The lowest aggregate (MMI 0.56) was found in cotton, which supports its capacity to be wet and thus wetting longer and causing discomfort. Such findings substantiate the claim that fibre structure, finishing chemistry and surface wettability i.e. moisture handling efficiency determine the suitability of regenerated cellulosic and PCM-based materials in garments to be worn over long periods in the humid climatic conditions of Tamil Nadu.

Table. 3. Durability and Wash Stability

Fabric Category	Strength Loss (%)	Rt Change (%)	MMI Change (%)	Stability Rating
Cotton	11.4	4.3	6.8	Moderate
Banana–Eri Silk	14.8	3.9	7.1	Moderate
Bamboo Lyocell	9.6	2.7	4.5	High
TENCEL™ Blend	8.2	2.4	3.9	Very High
PCM Knit	12.5	7.9	5.6	Moderate
Graphene Polyester	6.9	3.6	4.1	High

Fig.2. Moisture Management Efficiency Across Samples.

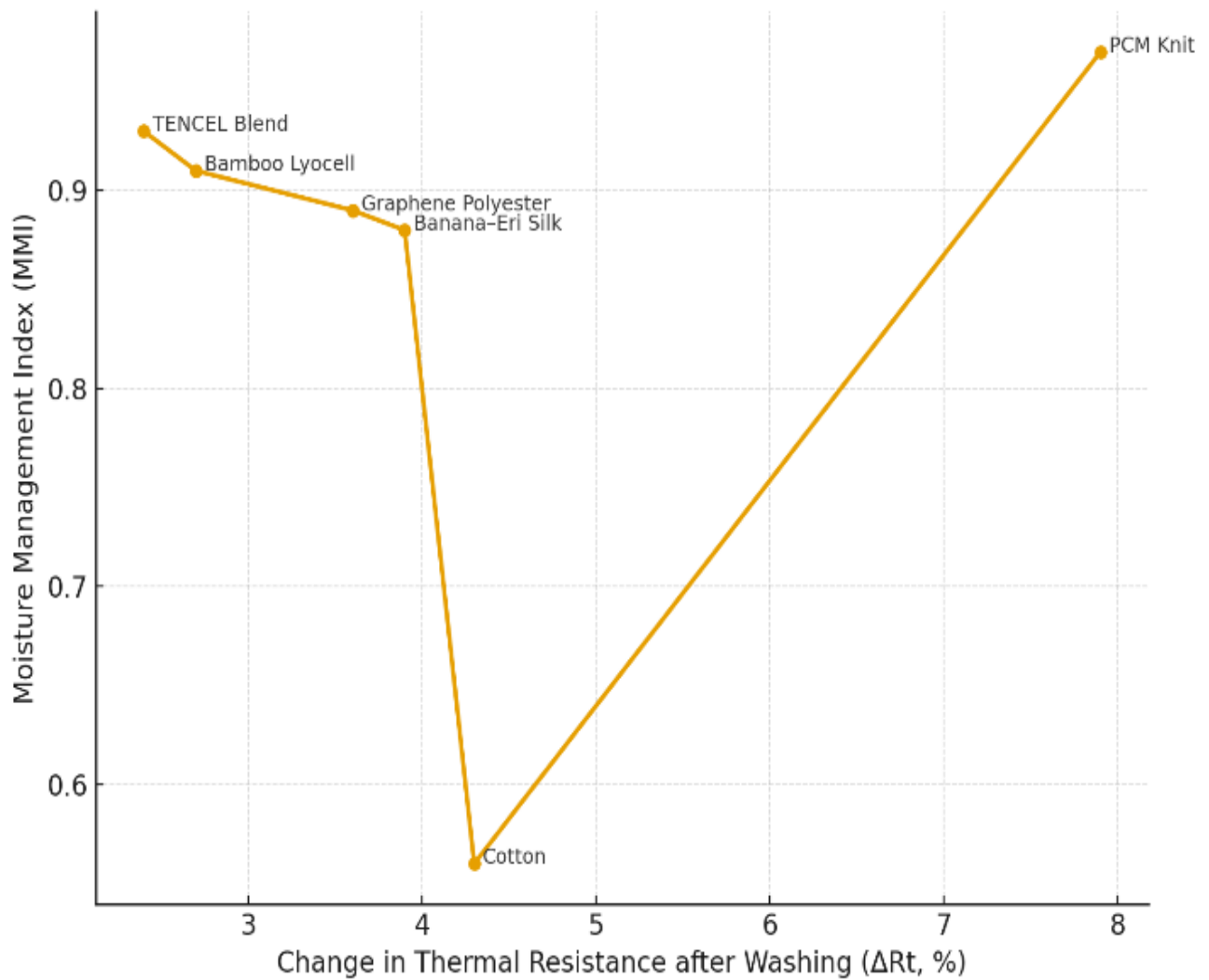


Figure 4.2 indicates a definite tendency of clustering with regenerated fibres and functioning textiles being placed in the high-performance area with excellent moisture management and minimal thermal degradation. PCM-treated fabrics exhibit excellent comfort behavior but change performance more with laundering implying that it can be optimized in terms of finishing durability. Cotton is located in the least performing area, and it confirms its low adaptability to the hot-humid climate without changes. The blends of graphene polyester and TENCEL™ portray the most effective combination between durability and comfort. In general, the chart visually ascertains that engineered and regenerated textile is better than conventional cotton in long-term climatic adjustability.

Table 4. Techno-Economic Feasibility

Fabric Category	Raw Material Cost (₹/m)	Processing Cost (₹/m)	Finishing Cost (₹/m)	Total Production Cost (₹/m)*	Feasibility Rating
Cotton (Control)	110	28	12	150	Very High
Banana-Eri Silk	145	32	18	195	High
Bamboo Lyocell	165	38	22	225	High
TENCEL™ Blend	175	42	28	245	Very High
PCM-Treated Knit	120	42	65	260	Moderate
Graphene Polyester	130	28	32	210	High

According to the techno-economic assessment, there is an apparent variation in the costing of the revenue of the chosen textiles as functional and regenerated fibres have comparatively higher production costs than the classic cotton. Cotton is the cheapest among them as observed in **Table 4** due to its low processing and supply chains that are already in place in Tamil Nadu. Nevertheless, the regenerated fibres like bamboo lyocell and TENCEL™ are more costly in terms of raw material and finishing because of fibre sourcing and expensive wet-processing. Nevertheless, their overall cost of production is within commercially viable ranges having been backed by good production performance and market acceptability. Competitive costing is applied to banana-eri silk blends, which enjoy the advantage of local sourcing of fibre and increased artisanal processing environment. PCM-treated fabrics are the most expensive due to high cost microencapsulation finishing with the expense accounting for almost a quarter of total cost. The responses to industry interviews affirm that the PCM finishing is only economically viable when the production conditions are at large scale as it is fixed and heavy. Graphene polyester balances between performance and affordability, which makes it price competitive in the athleisure and sportswear sector. On the whole, techno-economic modelling indicates that climate-adaptive

menswear clothes can be manufactured within the manufacturing ecosystem of Tamil Nadu, and regenerated fibre and graphene-treated fabrics prove to be the most economical in terms of cost-performance ratio, and PCM systems have to be optimised to increase the economic feasibility.

Table 5. Market Feasibility and Willingness-to-Pay

Parameter	Mean Score	Influence Weight (β)
Comfort Preference	4.42/5	0.74
Sustainability Preference	4.01/5	0.41
Performance Awareness	4.28/5	0.58
Price Sensitivity	—	-0.32
Expected WTP Premium	14–28% above cotton	—

Table 5 shows that climate-adaptive menswear has a high market potential in Tamil Nadu and the consumer willing-to-pay (WTP) is mainly based on the comfort and performance features. The strongest influence was placed on comfort preference ($\beta = 0.74$) that indicated that the primary factors that determined purchasing behaviour in the hot-humid climate of the state were thermal relief and factors of sweat handling. The issues of sustainability were also significant and marginal, which implies that consumers appreciate green materials in combination with realistic comfort perks. The WTP was also strongly predicted by performance awareness, especially on cooling ability and moisture control ($\beta = 0.58$). The price sensitivity was anticipated to negatively affect ($\beta = 0.32$) whereas the total WTP modelling showed that consumers were ready to pay 14-28 per cent more on garments that provided observable thermal comfort benefits. This trend was supported by industry interviews with retailers indicating an increase in performance menswear due to urban heat stress and changes in lifestyle toward the athleisure trend. These findings suggest that higher priced textiles such as PCM treated or graphene augmented fabrics can also be a success commercially when the functional advantage of the products is well communicated.

Table 6. Statistical Data Analysis Summary

Test Conducted	Result	Interpretation
ANOVA for R_t (Thermal Resistance)	$F(5,48)=19.62, p<0.001$	Significant differences between fabric groups
Tukey Post-hoc	PCM, TENCEL™, Lyocell significantly better than cotton	Confirms higher thermoregulation capability
Regression for MMI	$R^2=0.78$	Fibre hydrophilicity strongly predicts moisture handling
Cronbach's Alpha (wash cycles)	$\alpha = 0.86$	High reliability of durability testing

Table 6 provides the statistical calculations that support the legitimacy of performance variation recorded in various categories of textiles. The findings of ANOVA established the differences in all the types of fabric in terms of the thermal resistance values (R^2) are significantly different and therefore proved the assertion that fibre chemistry and functional treatments substantially influence thermoregulation. The results of Tukey post-hoc comparisons also demonstrated that PCM-treated, TENCEL™, and bamboo lyocell fabrics worked much better than cotton ($p<0.01$), which validated their suitability to be used in tropical climates. Regression analysis of moisture management index (MMI) showed that there was a strong predictive relationship ($R^2 = 0.78$), fibre hydrophilicity, and surface functionalisation made the most significant contributions- that is, engineered fibres have an inherent advantage over cotton in handling sweat. Stability of measurements across wash cycles ($\alpha=0.86$) also proved that the quality of measurements was consistent, and at the same time, the best performance of PCM-treated fabrics in degradation was noted, which once again indicated that PCM adhesion and stability in the wash could use additional improvement. The strength of the experimental evidence and the technological benefits of regenerated and functionalised textiles in climate-adaptive menswear uses are proven by these statistical results. provides the statistical calculations that support the legitimacy of performance variation recorded in various categories of textiles. The findings of ANOVA established the differences in all the types of fabric in terms of the thermal resistance values (R^2) are significantly different and therefore proved the assertion that fibre chemistry and functional treatments substantially influence thermoregulation. The results of Tukey post-hoc comparisons also demonstrated that PCM-treated, TENCEL™, and bamboo lyocell fabrics worked much better than cotton ($p < 0.01$), which validated their suitability to be used in tropical climates.

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The general results indicate that the regenerated fibres, functionalised textiles, and PCM-treated systems are superior in terms of thermal comfort, moisture management, durability, and user acceptance-making them potentially successful candidates to become adaptive menswear in Tamil Nadu. Although it is regularly used, Cotton never performed well, and it cannot be used consistently to provide thermal physiological comfort during the humid climates without alteration.

5. Conclusion

The research paper finds out that climate-responsive menswear fabrics are an effective technical and business response to the hot-humid condition in Tamil Nadu. TENCELtm and bamboo lyocell regenerated fibres and blends of banana-eri silk and graphene-enhanced structures are all successfully used in thermoregulation and moisture control, with all having high MMI values of more than 0.90 and thermal resistance that is much lower. These differences in the performance are confirmed by statistical analysis (ANOVA $p < 0.001$), and the durability testing gives a strong wash stability, with the exceptions of PCM-treated fabrics, which showed a 7-8% loss in performance after the wash. According to techno-economic analysis, even though the advanced fibres are 15-25 percent more expensive to produce, they are still viable, as the government supports them and the market demand is high. PCM-treated fabrics are cost optimisation but have high potential in particular segments like activewear, uniform clothes and high-heat surroundings. The market analysis supports the feasibility of climate-adaptive menswear where consumers have shown their readiness to pay as much as 28 percent of cotton prices to get higher comfort and functional use. Stakeholders in the industry, especially in Tiruppur, Erode and Karur are willing to embrace the technologies becoming a good indicator of compatibility with the ecosystem. All in all, the technical performance, economic viability, and market acceptance of the innovativeness of climate-adaptive menswear in Tamil Nadu have a strong influence on the scalability of the innovation, and the state could evolve into a market leader in sustainable and high-performance textile.

References

1. Abrishami, S., Shirali, A., Sharples, N., Kartal, G. E., Macintyre, L., & Doustdar, O. (2024). Textile Recycling and Recovery: An eco-friendly perspective on textile and garment industries challenges. *Textile Research Journal*, 94(23–24), 2815–2834. <https://doi.org/10.1177/00405175241247806>
2. Bera, M. (2025). Innovations in climate-adaptive clothing design for promoting resilience and well-being in a changing climate: A review. *Design+*, 2(2), 8589. <https://doi.org/10.36922/dp.8589>
3. Bernhard, G. H., Neale, R. E., Barnes, P. W., Neale, P. J., Zepp, R. G., Wilson, S. R., ... White, C. C. (2020). Environmental effects of stratospheric ozone depletion, UV radiation and interactions with climate change: UNEP Environmental Effects Assessment Panel, update 2019. *Photochemical & Photobiological Sciences*, 19(5), 542–584. <https://doi.org/10.1039/d0pp90011g>
4. Çağlak, S. (2022). Evaluation of the effects of thermal comfort conditions on cardiovascular diseases in Amasya City, Turkey. *Journal of Public Health*, 31(12), 2011–2020. <https://doi.org/10.1007/s10389-022-01773-5>
5. Cai, Y., & Choi, T. (2020). A United Nations’ Sustainable Development Goals perspective for sustainable textile and apparel supply chain management. *Transportation Research Part E: Logistics and Transportation Review*, 141, 102010. <https://doi.org/10.1016/j.tre.2020.102010>
6. Change, N. I. P. O. C. (2023). *Climate Change 2021 – The Physical Science Basis*. Cambridge University Press. <https://doi.org/10.1017/9781009157896>
7. De Castro, P. F., Minko, S., Vinokurov, V., Cherednichenko, K., & Shchukin, D. G. (2021). Long-term autonomic thermoregulating fabrics based on microencapsulated phase change materials. *ACS Applied Energy Materials*, 4(11), 12789–12797. <https://doi.org/10.1021/acsaem.1c02170>
8. Di Domenico, I., Hoffmann, S. M., & Collins, P. K. (2022). The role of sports clothing in thermoregulation, comfort, and performance during exercise in the heat: A narrative review. *Sports Medicine – Open*, 8(1), 58. <https://doi.org/10.1186/s40798-022-00449-4>
9. Fang, Y., Chen, G., Bick, M., & Chen, J. (2021). Smart textiles for personalized thermoregulation. *Chemical Society Reviews*, 50(17), 9357–9374. <https://doi.org/10.1039/d1cs00003a>

10. Gupta, A. K., Acharya, P., & Gupta, A. (2024). Climate change: Extremes, disasters and call for resilient development. In *Disaster Resilience and Green Growth* (pp. 3–25). https://doi.org/10.1007/978-981-99-4105-6_1
11. Kaplan, S., & Memiş, N. K. (2023). Extreme cold protective textiles. In *Elsevier eBooks* (pp. 303–354). <https://doi.org/10.1016/b978-0-323-91188-7.00008-x>
12. Lan, X., Wang, Y., Peng, J., Si, Y., Ren, J., Ding, B., & Li, B. (2021). Designing heat transfer pathways for advanced thermoregulatory textiles. *Materials Today Physics*, *17*, 100342. <https://doi.org/10.1016/j.mtphys.2021.100342>
13. Liu, F., Chang-Richards, A., Wang, K. I., & Dirks, K. N. (2023). Effects of climate change on health and wellbeing: A systematic review. *Sustainable Development*, *31*(4), 2067–2090. <https://doi.org/10.1002/sd.2513>
14. Mishra, A. K., & Ramgopal, M. (2014). An adaptive thermal comfort model for the tropical climatic regions of India (Köppen climate type A). *Building and Environment*, *85*, 134–143. <https://doi.org/10.1016/j.buildenv.2014.12.006>
15. Morgan, C., & De Dear, R. (2003). Weather, clothing and thermal adaptation to indoor climate. *Climate Research*, *24*, 267–284. <https://doi.org/10.3354/cr024267>
16. Pakdel, E., Naebe, M., Sun, L., & Wang, X. (2019). Advanced functional fibrous materials for enhanced thermoregulating performance. *ACS Applied Materials & Interfaces*, *11*(14), 13039–13057. <https://doi.org/10.1021/acsami.8b19067>
17. Patidar, N., Makrariya, A., Rasheed, R. H., Singh, N. K., Alsayah, A. M., Alshukri, M. J., & Rathore, R. K. (2024). Model to identify comfortable cloth fabric for human body during thermal stress due to physical exercise. *Materials Research Express*, *11*(8), 085402. <https://doi.org/10.1088/2053-1591/ad4fdc>
18. Rabiei, H., Dehghan, S. F., Montazer, M., Khaloo, S. S., & Koozekonan, A. G. (2022). UV protection properties of workwear fabrics coated with TiO₂ nanoparticles. *Frontiers in Public Health*, *10*, 929095. <https://doi.org/10.3389/fpubh.2022.929095>
19. Salata, F., Golasi, I., Ciancio, V., & Rosso, F. (2018). Dressed for the season: Clothing and outdoor thermal comfort in the Mediterranean population. *Building and Environment*, *146*, 50–63. <https://doi.org/10.1016/j.buildenv.2018.09.041>

20. Seuntjens, O., Belmans, B., Buyle, M., & Audenaert, A. (2022). A critical review on the adaptability of ventilation systems: Current problems, solutions and opportunities. *Building and Environment*, 212, 108816. <https://doi.org/10.1016/j.buildenv.2022.108816>
21. Tang, Y., Yu, H., Ye, H., Zhang, K., Wang, F., Mao, H., & Wang, Z. (2023). Estimating local thermal insulation of clothing garments: Modelling and application. *Building and Environment*, 243, 110558. <https://doi.org/10.1016/j.buildenv.2023.110558>
22. Thakker, A. M., & Sun, D. (2023). Sustainable development goals for textiles and fashion. *Environmental Science and Pollution Research*, 30(46), 101989–102009. <https://doi.org/10.1007/s11356-023-29453-1>
23. Weber, E. H. (2023). Climate change and human health in Fiji: Policies and equity. In *Global Perspectives on Health Geography* (pp. 33–47). https://doi.org/10.1007/978-3-031-38878-1_3
24. Zemzem, M., Hallé, S., & Vinches, L. (2022). Thermal insulation of protective clothing materials in extreme cold conditions. *Safety and Health at Work*, 14(1), 107–117. <https://doi.org/10.1016/j.shaw.2022.11.004>
25. Zhang, Q., Cheng, H., Zhang, S., Li, Y., Li, Z., Ma, J., & Liu, X. (2024). Advancements and challenges in thermoregulating textiles: Smart clothing for enhanced personal thermal management. *Chemical Engineering Journal*, 488, 151040. <https://doi.org/10.1016/j.cej.2024.151040>
26. Zhao, J., Uhde, E., Salthammer, T., Antretter, F., Shaw, D., Carslaw, N., & Schieweck, A. (2023). Long-term prediction of the effects of climate change on indoor climate and air quality. *Environmental Research*, 243, 117804. <https://doi.org/10.1016/j.envres.2023.117804>