Pakistan NDC Technology Roadmap for Waste and Water Sector

GENDER ASSESSMENT REPORT

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1. INTRODUCTION

Climate change, as an established global calamity, is made all the more perilous by its ability to disrupt each aspect of society in a unique manner. Its varying impacts on the developed and developing nations are well known, with Pakistan serving as a prime example to this phenomenon. A nation of 240 million people, with greenhouse gas emissions at 0.98%, Pakistan is ranked as the fifth most vulnerable nation to the impacts of climate change. In this instance, bringing in a gender perspective merely exacerbates the situation. The impacts of climate change vary not merely across the nation, but also for individual members of a household, with gender vulnerabilities being aggravated due to their socially constructed roles and responsibilities.[1]

The extent of this disparity was observed during the 2022 floods, where 650,000 pregnant Pakistani women were left without access to basic healthcare and were forced to deliver in unsanitary conditions.[2] Climate change has thus emerged as a social injustice, targeting the vulnerable and worsening their predicament; any discussion on climate change is rendered useless without addressing the plight of women and the vulnerable.[2] The need for this document, therefore, arises from gender and the vulnerable population, in particular the youth, being identified as beneficiaries in the Updated Nationally Determined Contributions 2021, Pakistan.[3] Focusing on the waste and water management sector, in particular, is a key step towards attaining gender equality as pledged by Pakistan in the Paris Agreement; while integrating the vulnerable population is fundamental to ensuring that adaptation and mitigation measures in the highly impacted communities and fruitful and prolific.[3]

It is important to understand a cumulative scenario of the waste and water management sector in Pakistan, in particular that observed in the rural areas. Pakistan generates a staggering 49.6 million tonnes of solid waste annually, that is increasing at an alarming rate of 2.4%/ year.[4] In regard to waste collection, it is estimated that 50% of the waste generated is collected; with urban waste often being left uncollected or dumped in open areas.[5] Inadequate sanitation, unaccountability, and lack of proper disposal sites often observe hazardous waste, such as that generated from the hospitals, getting mixed with general waste, exacerbating the challenges of safe waste management. Waste generation and safe disposal is an issue that is prevalent in the agriculture sector also. With 47% of the total land area being dedicated to agricultural practices, the production in the agriculture sector indicates significant levels of waste and residue from both Rabi and Kharif crops.[6] Waste generated from animal manure is estimated to be at 2.5 million tons from a total of 196 million livestock over one full day. Most of this waste and residue generated in Pakistan is openly combusted and some landfilled, with the burning of this waste contributing to the national emissions of greenhouse gases such as carbon dioxide, nitrogen oxide, and methane.[5]

Another sector of interest is that of water management and sanitation. Pakistan as a developing nation bears the brunt of challenges associated with safe and adequate water

[1] Abbasi, S.S., et al. (2018). Identifying gender vulnerabilities in context of climate change in Indus Basin. Retrieved from: https://doi.org/10.1016/j.envdev.2018.12.005

[2] Climate Change's greatest victims are women and girls, UNICEF https://www.unicef.org/rosa/blog/climate-changes-greatest-victims-are-women-and-girls#:~:text=The%20UN%20estimates%20that%2080,birth%20under%20the%20open%20sky

[3] Updated Nationally Determined Contributions 2021, Pakistan. . https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf

[4] Pakistan - Country Commercial Guide, , https://www.trade.gov/country-commercial-guides/pakistan-waste-management

[5] Solid Waste Management Sector in Pakistan . A Reform Road Map for Policy Makers March 2022 . https://www.adb.org/sites/default/files/publication/784421/solid-waste-management-pakistan-road-map.pdf

[6] Pakistan at a Glance. FAO in Pakistan. https://www.fao.org/pakistan/our-office/pakistan-at-a-glance/en/#:~:text=Agriculture%20Sector&text=About%2070%20percent%20of%20Pakistan's,global%20average%20of%2038%20percent

availability. Poor water management and an accelerating population are two defining factors that exacerbate this issue. It has been estimated that by 2025 Pakistan will observe an 8% increase in water demand cross sectors spanning agriculture, industry, and domestic use.[7] It if further projected that Pakistan's water availability/ person is expected to drop to 800m^3 by 2025, well below the safe limit.[8] Perhaps it comes as no surprise that access to safe drinking water, is a rising challenge for Pakistanis, in particular those that are vulnerable and live in far-flung rural areas. Only about 20% of the population has access to clean water, leaving a staggering 80% to rely on unsafe sources. This scarcity is due to two main reason: contamination due to sewage, the primary culprit, that is often dumped directly into water supplies; followed by pollution in the form of industrial waste, pesticides, and fertilizers from agriculture all contribute to toxic chemicals in the water. These anthropogenic activities are a major cause of waterborne diseases, with these diseases making up a staggering 80% of the burden of disease in Pakistan and are responsible for a shocking 33% of deaths in the country. [9]

Pakistan faces challenges in both waste management and water security, with the women, youth, and the vulnerable community being disproportionately affected. Gender-based technological interventions are crucial for addressing these issues. Traditional gender roles often place the responsibility of water collection and waste disposal on women, who may lack access to efficient technologies or decision-making power. By empowering women, and the vulnerable section of the population, with technology, these interventions can improve efficiency, safety, and health outcomes, ultimately leading to a more sustainable future for Pakistan's waste and water sectors.

2. Gender Gaps & Inequalities in Pakistan

The global definition of gender equality encompasses the fundamental concept of ensuring that both men and women not only have equal access to available resources, rather are also provided with equal prospects to reap the benefits of these resources[10]. For any nation, regardless of its development status, gender equality comes about by activities promoting empowerment and informed choices[10]. SDG 5: Gender Equality is the global embodiment of the need for the integration of this essential human right[11]. A level playing field, that provides equal opportunities for both genders, is the key for achieving reduced poverty, improved health, safety, and ensuring quality education for both boys and girls[11].

Our focus now shifts to Pakistan, where out of the total population, 49.6% of them represent the female population[12]. Pakistan's road to development has long faced hindrances in the form of increasing poverty, inequality, economic distress, socio-political vulnerabilities, and recurrent natural disasters that are being exacerbated by climate change. It perhaps, comes as no surprise, that these barriers disproportionately impact the female population of this developing nation[12]. As per the Human Development Report's 2022 Gender Inequality Index, Pakistan is ranked 161st out of a total of 191 countries[13].

[7] Parry, J.-E. (2016). The vulnerability of Pakistan's water sector to the impacts of climate change: Identification of gaps and recommendations for action. New York, NY: International Institute for Sustainable Development.

[8] Qureshi, R., and Ashraf, M. (2019). Water security issues of agriculture in Pakistan. PAS Islamabad Pak 1, 41.

[9] Daud MK, Nafees M, Ali S, Rizwan M, Bajwa RA, Shakoor MB, Arshad MU, Chatha SAS, Deeba F, Murad W, Malook I, Zhu SJ. Drinking Water Quality Status and Contamination in Pakistan. Biomed Res Int. 2017;2017:7908183. doi: 10.1155/2017/7908183. Epub 2017 Aug 14. PMID: 28884130; PMCID: PMC5573092.

[10] Applying a Gender Lens to Science, Technology and innovation. United Nations Conference on Trade and Development (UNCTAD)

[11] Sustainable Development Goals. Goal 5: Achieve gender equality and empower all women and girls.

[12] The World Bank. Population, female (% of the total population)-Pakistan.

[13] Development Advocate Pakistan, 9 (14). 2022. UNDP

In certain dimensions the effect of this disparity is magnanimous, such as those observed in the education sector. Despite there being more girls in school, gender disparities during enrolment still exist, with this situation worsening as girls move from primary to middle school[14]. Availability to quality education is still a challenge for the female population, with an alarming 12 million girls contributing to most out-of-school population in Pakistan[15]. Furthermore, girls belonging to poor families, particularly those situated in the rural areas, are further less likely to be enrolled in school limiting their chances for future financial prosperity[15]. Not only education, but gender disparities are observed in the healthcare system as well. While steps are being taken to gain control on differentials in child immunizations, high maternal mortality, in particular in the rural areas, still persist due to hindrances in accessing and provision of reproductive health services, and the requires prenatal and postnatal care[16]. Gender-based violence, poor living standards, lack of education and lack of access to proper healthcare further supresses the growth of the segment of the Pakistani population.

Girls not only lack access to health and education resources, rather face disparity when it comes to employment options, particularly in the informal sector[17]. The Key Findings of the Labour Force Survey, conducted in 2020-21, paint quite a depressing picture. Covering the entire span of Pakistan, only 21% of the female population was employed in the informal sector, as opposed to 52.5% male employment[18]. On the other hand, the disparity appears to be closing in the employment trends as observed for the agriculture sector; with 65.5% of the employed being females, with 73.4% being males, and an average employment percentage of 72.5%[18]. Economic disparity in Pakistan is mostly driven by the low societal status of women, socio-cultural humiliation practices, with increasing harassment incidences, against women, in the workplace. Lower literacy rates, early marriages, mobility restrictions, lack of required skillset, sex-aggregated occupational choices, and the cultural norm for prioritising household chores over any other human right, for the female population of Pakistan serve as obstacles in attaining financial security and independence. A patriarchal society further prevents women from achieving leadership or managerial positions, with the Labour Force Survey 2020-2021 that only 7.6 proportion of females in the rural areas, and 4.9 proportion of females in urban areas are employed in managerial positions[18]. This further prevents women from being involved in decision making processes, with lower wages, and an unfavourable work environment further preventing them from staying long at their jobs[16]—economic growth for women seems to be merely a far-fetched dream.

The need to address gender inequality in Pakistan arises not only due to the restriction it places on economic development, but because of the glaring fact that climate change impacts, themselves, promote disparity[13]. Women are at the receiving end of disproportionate violence, are more prone to displacement, suffer greater loss of livelihood, with natural disasters further preventing women from accessing healthcare and educational facilities[13] The 2022 floods were particularly devastating to the women residing in rural areas, due to their high engagement level in the agriculture sector, and a limited capacity to deal with the associated climate induced risks. The current crisis has increased the vulnerability 640,000 adolescent girls to increased risk of coercions, gender-based violence, and child marriage[13].

[13] Development Advocate Pakistan, 9 (14). 2022. UNDP

[14] Pakistan Country Gender Assessment; Bridging the Gender Gap: Opportunities and Challenged. 2005, UNDP.

[15] Barón, JD & Bend, M. Facing the Challenges of Girls' Education in Pakistan. 2023. https://blogs.worldbank.org/en/education/facing-challenges-girls-education-pakistan

[16] Ali et al. Perpetuation of gender discrimination in Pakistani society: results from a scoping review and qualitative study conducted in three provinces of Pakistan. BMC Women's Health, 2022; 22: 540. https://doi.org/10.1186%2Fs12905-022-02011-6

[17] Rana, Q. et al. Gender Inequality in Pakistan: An Assessment. https://pssr.org.pk/issues/v6/2/gender-inequality-in-pakistan-an-assessment.pdf

[18] Key Findings of Labour Force Survey 2020-21. Government of Pakistan; Ministry of Planning, Development & Special Initiatives. Pakistan Bureau of Statistics. March 2022.

Climate catastrophes such as droughts, Glacial lake Outburst Floods (GLOFs), and other risks further increase the risk of women receiving the brunt of the disaster. Lack of economic empowerment prevent the female population Pakistan from adapting to the impacts of climate change. In this regard Pakistan's Climate Change Gender Adaptation Plan (ccGAP), has risen as a champion to increase the resilience of women across the nation[19]. This plan was designed to operationalise the commitments set in national climate change policies and plans, and to ensure subsequent gender mainstreaming. The importance of women being represented in decision making activities is fundamental to ensure effective responsiveness to natural disasters, promote natural resource management, ensure food security and to lead their society towards being climate resilient. ccGAP further highlights that community responsiveness increases once women are included in the policy making process.

As a signatory of the Paris Agreement, Pakistan is committed to promote gender equality. This section, therefore, aims to present a baseline analysis of gender gaps and inequalities as present in both the waste and water sectors. It will assess the current roles of women and men in waste and water management. The accompanying technological assessment, conducted through a gender lens, will further aid in identifying potential gender gaps, and steps that can be taken to promote women's participation in the implementation of new technologies, and enhancements of existing technologies. Both the baseline analysis, and technological assessment will feed into the steps that need to be taken to develop gender inclusive strategies that bridge the existing gaps, promote gender equality, and lead Pakistan towards a sustainable and climate resilient future.

2.1 Gender Gaps & Inequalities in Pakistan: Waste Sector

Solid waste generation, and its collection, represents a major plight for majority of metropolitan cities of Pakistan. Approximately 49.6 million tons of solid waste is generated by Pakistan, on an annual basis, with trends demonstrating an increase rate of 2.4% annually[20].

Delving deep in the labour composition of this sector, we find the assumption of waste management to be gender neutral being overshadowed by the harsh reality of poignant gender disparities being visible throughout various aspects of this industry. Women have the lead at the household level, dominating activities such as recycling, reusing, and informal waste management; however, their representation in formal employment, in particular waste management, remains limited and over-shadowed by a patriarchal industry culture. Pakistan, with its strict socio-cultural norms and traditional school of thought, particularly in rural areas, reflects this disparity at all levels of the waste management sector.

Deeply ingrained socio-cultural norms serve as the primary barrier preventing women from progressing economically in the waste management sector. Traditional norms, particularly in the rural areas, dictate women to cater to domestic responsibilities, with societal disdain of women being seen working outside the "four walls" of their residence further restricting their presence in the formal waste sector workforce, and renders their economic contribution to be overlooked. [21] Furthermore, traditional gender roles dictate the position of both the genders in the value chain: men are placed higher up and deal with managerial roles, while women are limited to menial tasks such as waste picking, sweeping and separating waste.

[19] Climate Change Gender Action Plan of the Government and People of Pakistan. 2022.

[20] Pakistan—Country Commercial Guide. Official Website of the International Trade Administration. 2024.

[21] Women entrepreneur in Pakistan; How to improve their bargaining Power. https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_094011.pdf

High-income and decision-making positions, including those revolving around business ownerships, transportation, and management of these entities are often devoid of women, with men dominating leadership positions in the waste value chain. The former is assigned menial roles such as waste picking, sorting, and segregation in landfill sites or on curb sides, based on the chauvinist assumptions that women are not only keen to detail but tend to multitask more efficiently. Women are further shunned from emerging as a major labour force in the formal sector, continues the cycle of poverty, economic seclusion, and limits the contribution of the female population to the circular economy.[21]

Such is the discrimination that gender disparity is observed in groups of scavengers as well. As with other sub-sections of the waste sector in Pakistan, this segment tends to be male dominated. In a study conducted by Asim et al.[22], the city of Lahore bears witness to female scavengers being limited to household waste collections and dumpsites, that too in the presence of their families. Socio-demographic characteristics of the scavengers, in the same study, demonstrated that no females were employed as itinerant buyers, street pickers of transfer point pickers. As opposed to this, itinerant buyers were composed of 80 males, street pickers were composed of 50 males, while transfer point pickers consisted of 15 males[22].

Figure 1: Waste Collection & Management Challenges faced by women in waste sector in Pakistan

Cultural expectations play a major role in defining these trends, as women are expected to travel with their male counterpart, the absence of which might restrict their reach to far-off waste collection points. Fear of sexual harassment by male workers, further compels the female workforce to work in groups. Widows tend to work alone, however, for the sake of their safety and to comply with traditional rules and norms, they are often accompanied by their relatives who are also in this industry[22]. Additional challenges are shown in Figure 1:

[21] Women entrepreneur in Pakistan; How to improve their bargaining Power. https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_094011.pdf

[22] Asim et al. Scavengers and their role in the recycling of waste in Southwestern Lahore. Resources, Conservation and Recycling. 2012; 58: 152-162.

The impact of this discrimination is reflected in waste management processes. Women inclusion in this sector will primarily eradicate the issue of limited waste segregation. Managing household waste usually comes under their jurisdiction, however limited mobility, and cultural norms, prevent them from performing waste segregation; in particular if the collection points are not within their access. Their absence from the formal sector creates a hindrance in ensuring effective disposal of household waste, based on its composition. This segregation further bars the way for any innovation that can be introduced to make this sector even more sustainable. It hinders the flow of diverse perspectives and experiences that women bring to any sector. Notions pertaining to waste, reduction, recycling, and community engagements go untapped due to this segregation. Seclusion further results in safety and security concerns, with cultural norms further restricting women to gain financial independence and to cater after themselves. These abusive work-conditions are further aggravated by women being shunned from the formal sector.

The need for inclusive development, arises not only from the need to propel women forward in the formal sector, but also due to the health issues attached with working in the informal waste sector. For the male workforce, the primary health concerns arise from the lack of safety equipment that exposes them to toxins and pathogens exposing them to a variety of bacteria, viruses and chemicals[23]. Biological hazards are accompanied by respiratory issues, skin problems and bloodborne diseases[23].

Women working in the informal sector are further exposed to toxins and pollutants that give rise to respiratory problems, skin problems, and are at increased risk of contracting infectious diseases such as diarrhoea, dysentery, hepatitis and typhoid[24]. Women working in landfill sites, or as scavengers, are more prone to develop breast cancer, have respiratory issues, and most importantly it adversely impacts the neonatal health, placing both mother and baby at risk.[24],[25] It is imperative that we shift this sector from a male dominant industry to an inclusive and safe workplace, where equal opportunities are provided in order to steer Pakistan towards a sustainable economy.

2.2 Gender Gaps & Inequalities in Pakistan: Water Sector

Pakistan has been ranked as the 14th most extremely high baseline water-stressed nation, out of only 17 countries, according to World Resources Institute[26]. Further elaborating on this alarming situation, IMF has presented a steep decline in Pakistan's per capita annual water availability that has reduced from 1500m^3, in 2009, to 1017m^3, in 2021[27]. By 2025 it is further estimated that the water availability will not only fall to 247 million acre-feet (MAF), but it will create a deficit of 83 MAF in demand and supply, as the available water resources remain at 191 MAF.[28] As Pakistan heads towards water scarcity, and insecurity, it exacerbates inequality not only amongst the socio-economic groups, but also widens the difference in the vulnerabilities as experienced by the two genders.

[23] Black, M., Karki, J., Lee, A.C.K. orcid.org/0000-0002-9795-3793 et al. (5 more authors) (2019) The health risks of informal waste workers in the Kathmandu Valley: a cross-sectional survey. Public Health, 166. pp. 10-18. ISSN 0033-3506

[24] Kihal-Talantikite W, Zmirou-Navier D, Padilla C, Deguen S. Systematic literature review of reproductive outcome associated with residential proximity to polluted sites. Int J Health Geogr.(2017) 16:20.

[25] Vryheid M. Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature. Environmental Health Perspectives. 2000; 108:101–112. doi: 10.1289/image.ehp.v108.i12.

[26] Experts Raise the Alarm on Growing Water Insecurity in Pakistan. https://www.aku.edu/news/Pages/News_Details.aspx?nid=NEWS-002910#:~:text=The%20World%20Resources%20Institute%20has,stress'%20countries%20of%20the%20world

[27] Growing water crisis disastrous for Pakistan's stability. ANI. https://www.aninews.in/news/world/asia/growing-water-crisis-disastrous-for-pakistans-stability-says-report20210909124218/

[28] Staff Team I. Issues in managing water challenges and policy instruments: regional perspcectives and case studies. IMF, 2015. https://www.imf.org/external/pubs/ft/sdn/2015/sdn1511tn.pdf

While both men and women are observed to share the responsibilities pertaining to the use, management, benefit sharing, and decisions related to water; the disparity arises in the form of different concerns, needs, unequal access to, and control over water resources. At a household level, women emerge as the active managers of water for household consumption and productive use pertaining to the agriculture sector. However, this leadership ends here, as a patriarchal society limits their participation in decision-making activities, processes, along with economic and technical advancements as professions in the water sector. It is such that Pakistan observes its female population to hold less that 6% of all federal ministerial positions in the domain of environment, natural resources, and energy.[29]

The primary disparity is observed in the rural areas, where women are not only expected to work in the household but are also supposed to fulfil their primary duties of cleaning, cooking, and fetching water from far-flung areas. As water-scarcity and insecurity takes hold, freshwater is not readily available nearby, adding to the women's responsibilities and forcing them to travel long distances in order to gain access to drinking water. It has been estimated that roughly 72% of household water is carried by women, in particular those hailing from rural areas, slums and villages that are in the grip of droughts.[30] Rural areas of Gilgit-Baltistan, Balochistan and Sindh, have observed their female population to travel as much as four kilometres, every day, on foot, to provide water for themselves and their families.[26]

The impact on women's lives is harrowing. Excessive time spent in carrying water to and from the source decreases the time spent by girls in school. This results in them either unable to attend school regularly, dropping out of school or struggling to pass the basic primary level of education. With 12 million girls accounting for the largest out-of-school population in Pakistan[31] this further sets the female population back in attaining financial security and independence.

Another adverse impact is felt by the health of the women. These far-off trips lasting of hours, are carried out regardless of the weather. Women travel with heavy clay pots that expose them to spinal pain, complications and risks during pregnancy, more susceptible to injuries, heat strokes, dehydration, and places an additional burden on their mental health.[32] But perhaps, the greatest gender disparity faced by rural women in water sector are the sexual and physical assaults that they are put through as they undertake long and arduous journeys to provide water for their households. This tends to particularly prevalent when the male of the family are forced to migrate, a lack of male family member further leaves the left-behind women more susceptible to sexual violence by strangers. Tharparkar, in particular Thari women, have been observed to suffer from mental health issues, such as anxiety and depression, followed by high suicide rates that have been linked to water scarcity.[27]

[29] Water and gender, Securing water for improving rural livelihoods. https://www.icimod.org/event/water-and-gender/

[30] Jamshaid, S.J. Opinion: Women bear the brunt of Pakistan's water crisis. Dialogue Earth, 2022. https://dialogue.earth/en/water/pakistan-women-water-crisis-jobs/

[31] Barón, J.D. & Bend, M. 2023. Facing the Challenge of Girls' Education in Pakistan. https://blogs.worldbank.org/en/education/facing-challenges-girls-education-pakistan#:~:text=About%202%20million%20more%20girls,20.3%20to%2022.1%20million%20children.

[32] Sheikh, N. Op-Ed: Water Scarcity in Pakistan Is a Gendered Issue. https://earth.org/world-water-day-2024-water-scarcity-in-pakistan-is-a-gendered-issue/

The greatest impact however, on women, is observed in the form of lack of access to adequate water, sanitation and health (WASH) facilities that increase the burden of disease as felt by the female population of Pakistan. Poor menstrual hygiene, and access to WASH facilities is a driving force for girls to drop out of school, and for prevalence of urinary infections. Not only education, but this prevents women for actively participating in the labour force, further diminishing their role in the economy. The figure below shows the link between gender, and water scarcity (UNICEF, Pakistan):

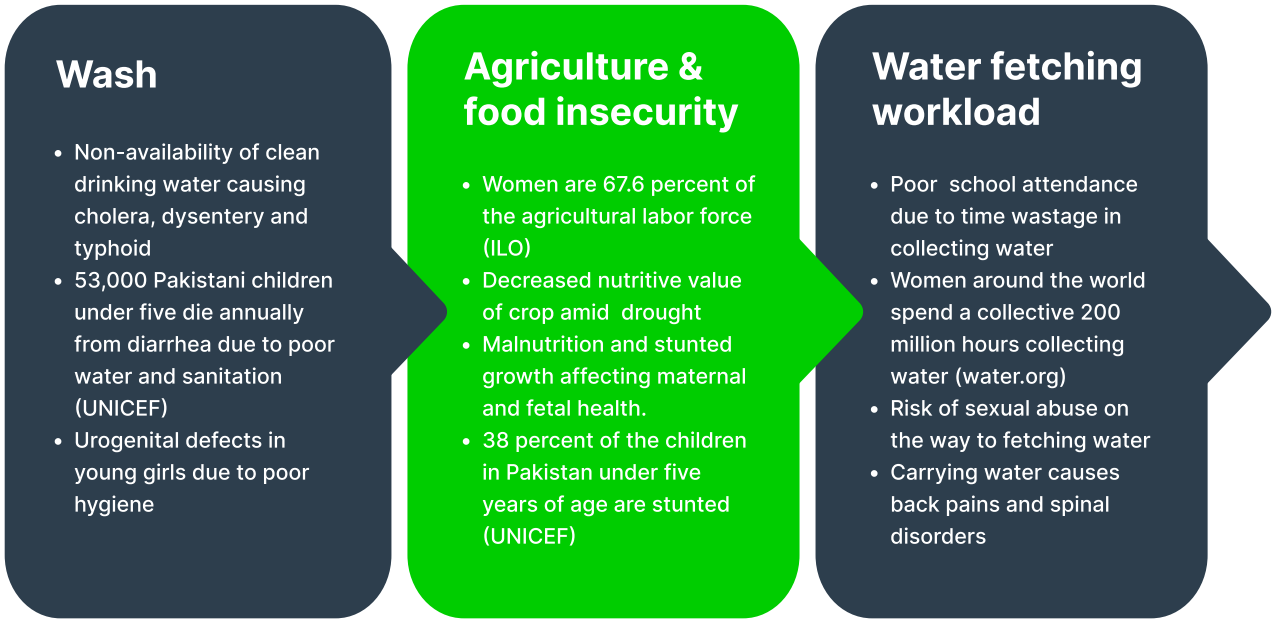

Figure 2: Water Scarcity and gender disparity (UNICEF, Pakistan).

Despite the role of women as household water managers, there is a need to address the disparity felt by this gender in the water sector. Steps need to be taken to reduce their vulnerabilities, to allow them to have a greater say in the decision-making processes, and to prioritize women involvement in policies, programmes and infrastructures pertaining to water management. Water is a basic human right, its access, and control should not be limited to one gender only. Participation of women should be prioritized and ensured at all levels—a feat that is vital for safeguarding Pakistan's water resource, and to help this nation overcome water scarcity and severity.

3. Youth-based Gaps & Inequalities in Waste and Water Sectors

With a considerable percentage of Pakistan's population (67%) belonging to the category of being under 30, this nation has a unique opportunity to thrive by investing in the development and empowerment of its young people[10]. With the establishment of the Green Youth Movement (GYM), the future of Pakistan was engaged in internships/ activities focusing on agriculture and forestry, liquid and solid waste, water, renewable energy and eco-tourism.[33] Focusing on Youth engagement in the waste and water sectors the GYM clubs have been formed in HEC renowned universities to carry out activities such as clean-up drives, university

[33] Prime Minister's Youth Programme Green Youth Movement. Accessed April 1, 2024. https://www.hec.gov.pk/english/services/students/PMYP/Pages/GYM.aspx

waste audits, water conservation drives and awareness sessions to educate community about waste and water sustainable use and conservation practices. The focus areas of these internships were natural resource conservation, sustainable resource consumption, waste management, climate change, eco-preneurship, green energy and disaster management.

3.1 Youth Analysis: Waste Sector

Major types of solid waste generated in Pakistan include municipal solid waste (source: households, offices, hotels, shops, schools and etc.), industrial waste (source: construction material, scraps, effluents, and mining activities), agriculture waste, electronic/ e-waste, and healthcare waste (source: hospitals, healthcare facilities, dispensaries, blood banks, private clinics, diagnostic and testing labs).[34] Youth engagement in waste sector can be divided into two types of categories based on family background, level of education and financial status of the young people involved. Youth coming from educated background are more engulfed in awareness and capacity building side of the waste management sector. These people are supported by their educational institutes to work on innovative ideas in developing waste management strategies and creating awareness through door-to-door educational campaigns. However, the youth coming from uneducated, and marginalized minorities and communities are engaged in waste- picking and segregation activities. In Pakistan men, women and children are involved in waste picking which is the sorting and collection of recyclable waste from dumpsites, waste heaps, roadside dustbins, and residential areas for the purpose of selling to junkyards.[11],[35]

Potential technologies in which Pakistan's youth can work on for waste management includes incorporating AI and smart sensors for creating smart bins that aid in separation of recyclable material from waste. Innovative technologies should be explored to convert waste to energy and biofuels providing sustainable energy alternatives and composting solutions should be proposed to convert organic waste into compost used for soil enrichment. Over the time youth has become more educated and aware about adopting sustainable practices for waste minimization, following this a new trend of sustainable fashion has been born to reduce waste generation from the fast fashion industry making people more conscious about their buying choices.

Youth's involvement through sustainable entrepreneurship, innovation and advocacy can significantly contribute to achieving SDGs for achieving sustainable development and waste management. However, unleashing the full potential of youth requires public and private cooperation, financial funding, adequate research infrastructure and technical guidance. By investing in youth empowerment, education and institutional support Pakistan can foster generations of change-makers in establishing a resilient and sustainable waste sector.

[34] Rapid assessment of child labour in waste-picking in Pakistan (International Labour Organization (ILO)), 2023.
[35] KOICA-World Bank Joint Study on Solid Waste Management in Punjab, Pakistan

3.2 Youth Analysis: Water Sector

As the sixth most populous country in the world, having a meagre 2% annual growth rate, Pakistan's investment in water and sanitation services are barely keeping pace with the population growth in the nation[36]. As a semi-arid country that relies heavily on the Indus River and its tributaries for water, over-exploitation and environmental degradation has heavily degraded water quality and quantity[37]. According to the National Water Policy 2018, issues concerning water sector includes water scarcity, water storage, water equity and untreated wastewater disposal[38].

Youth involvement in water sector is mainly through educational societies in their universities through which they initiate public campaigns and awareness sessions for educating the community on water conservation and management. A WaterWise Summit on the theme of Respect Water-Respect Life was organized by COMSATS for spreading awareness on saving water and educating about climate change induced disasters such as flooding[39]. Pakistan Water Week 2023, organized by PCRWR in collaboration with IWMI, UNICEF and partners, focused on a transformative approach. Several activities were designed to engage the youth such as debate competitions, technology exhibitions, and engineering competitions to unleash their true potential via healthy competitions and out-of-the-box ideas sharing for overcoming water related issues[40]. The potential technologies in which youth can creatively work to overcome water related challenges include rainwater harvesting, advanced water purification techniques, smart irrigation, smart desalination techniques and remote sensing and AI technologies for efficient water resource mapping and monitoring. Other than this, well-thought-out outreach programs should be initiated by young change-makers through community-based water management solutions.

Water sector offers a number of opportunities in engaging the youth of Pakistan via research, innovation, and advocacy. Despite opportunities for youth engagement a significant challenge faced by the youth involves lack of access to quality education and training opportunities. This creates a knowledge gap to explore innovative techniques in water-related fields, limiting the potential contribution to the sector. Lack of advanced effective water management systems, wastewater treatment facilities and irrigation systems not only affects the water accessibility but also hinder environmental sustainability and economic development.

Engaging youth will bring in fresh perspective, innovative ideas, and sustainable solutions to deal with the conventional problems associated with waste and water sector. Youth engagement will help in understanding local context and grass root challenges for prioritized sector development.

[36] Urban WASH Behavioural Determinants, 2020.

[37] National Water Conservation Strategy for Pakistan (2023-2027).

[38] National Water Policy, Pakistan 2018

[39] COMSATS. Waterwise Summit: Unveiling Solutions Through Youth Voices. Published January 12, 2023. Accessed February 4, 2024. https://cuiwah.edu.pk/Home/Blog/2515

[40] Pakistan Water Week 2023. Accessed April 2, 2024. https://pcrwr.gov.pk/pakistan-water-week-2023/

4. Social Inclusion Gaps & Inequalities in Waste and Water Sectors

Drinking water and sanitation are the most essential elements for human life and its dignity. Poor water and sanitation not only harms the human health but also gives birth to multiple socio-economic and environmental concerns. Each year, more than 3 million Pakistanis get infected by water-borne diseases. Punjab in particular faces the most extreme case of inequality to WASH services, with socio-economic factors playing a major role in access to safe drinking water and improved sanitation services, across the districts, with less developed districts facing the greatest inequality[41]. Similarly, rural areas report the greatest vulnerability, with 71% of the rural households reporting inadequate sanitation facilities, increasing the vulnerability of the marginalized communities[42]. Furthermore, in terms of waste management, the biggest challenge presently is the collection, transportation, and disposal of domestic solid waste, resulting in the environmental and sanitary conditions being complex and unhygienic[43].

Low-income households, ethnic minorities and elderly female headed households are usually affected disproportionately due to lack of water and sanitation services. Women and girls in conservative poor communities or tribal areas are predominantly affected due to inaccessibility of water and poor sanitation facilities yet are side-lined during the relevant decision-making process[19]. Patriarchal society and cultural norms further limit the participation of women, differently abled persons and marginalized groups in community decision-making, which also includes decisions related to their everyday well-being[44]. Inadequate water supply and sanitation facilities induces a burden of PKR 116.13 billion of the health cost on lower-income households[45].

High level of population growth and rapid urbanization have result in inadequate management of municipal solid waste. Due to improper waste disposal practices, private stakeholders are dominating waste recycling and segregation activities, with lack of government oversight leading to communities from low-income background, migrants from rural areas and women and children of the Afghan refugees to become waste-pickers in order to afford livelihood. They work for long hours exposing themselves to unhygienic conditions and face social stigma, verbal abuse, and even physical violence[46],[47]. Various national policies have incorporated special measures for access to WASH facilities for marginalized groups like women, children and differently abled persons. However, the inclusion of these marginalized groups is inconsistent throughout the policy framework contributing to lack of increased access to WASH for these groups[48].

[41] Inequalities in Access to Safe Drinking Water and Improved Sanitation based upon Household Socio-economic Factors within Districts of Punjab - Punjab Economic Research Institute.

[42] Hakro AN. Water, Sanitation and Poverty Linkages in Pakistan.

[43] Hashmi H, Ejaz N, Naushad Z, Ali Z. Impacts of solid waste management in Pakistan: a case study of Rawalpindi city, 2008:685-691. doi:10.2495/WM080701

[44] LIFE lessons on inclusive WASH action in Pakistan. Published December 2, 2023. Accessed April 4, 2024. https://www.waterforwomenfund.org/en/news/life-lessons-on-inclusive- wash-action-in-pakistan.aspx

[45] Report R. Inadequate water supply burdens low-income households with Rs116bn health cost. Brecorder. Accessed April 4, 2024. https://www.brecorder.com/news/40291446

[46] Rapid assessment of child labour in waste-picking in Pakistan (International Labour Organization (ILO)). Accessed April 1, 2024. https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-islamabad/documents/publication/wcms_887600.pdf

[47] Marginalized informal recycling and the start of waste-to-energy in Lahore, Punjab, Pakistan - Ej Atlas. Accessed April 7, 2024.

[48] Policy Paper for WASH (2021).

Yet, steps are being taken to introduce the latest technologies in collaboration with international and local organizations to ensure water accessibility and proper waste disposal. Despite these measures, rural and marginalized communities often lack proper sanitation, such as toilets and latrines leading to open defecation causing contamination in nearby ground water resources. These communities lack access to adequate information, technology and infrastructure making effective waste and water management a challenge. Differently abled persons face socio-economic disparities such as unemployment and poverty that further creates hindrance in accessing essential services. These vulnerable populations face issues in terms of accessibility to proper sanitation facilities due to absence of important features in public toilets such as wide toilet doors, ramps, and handrails. Lack of smart assistive technology in toilets make differently abled persons more vulnerable to injuries and accidents.

Therefore, a multi-faceted approach should be adopted to promote inclusion and ensuring accessibility in the waste and water sector. Investment in appropriate technologies, capacity building, community engagement and inclusion of marginalized communities should be ensured to achieve region specific smart solutions for overcoming water and waste related issues. Targeted trainings should be carried out for raising awareness about disability rights and inclusion in order to adequately address sector related initiatives. Accessibility of water demand should be based on equity and poorer households should not be disproportionately burdened[49].

5. Technology Assessment through a Gender Lens

The need for technology development, integration of new technology, and technological cooperation are an integral part of NDCs implementation in Pakistan. This step is further needed to ensure that the set adaptation and mitigation targets, in all sectors of Pakistan, are achieved—leading Pakistan towards a sustainable, and climate resilient future. Technology transfer is further needed to ensure that Pakistan fulfils the requirements as set down by Article 4 of UNFCCC, along with Articles 9, 10 and 11 of the Paris Agreement that are the key to ensuring complete implementation of the climate actions as highlighted in the NDCs.

This section explores and presents a gender-based perspective on the technologies that are both existing and emerging for the waste and water sectors, in Pakistan. A gendered understanding of technologies being introduced in these sectors is vital for the success of interventions that aim to promote urban economic development, ensure long-term ecological sustainability, and promote social justice[50].

5.1 METHODOLOGY:

5.1.1 Selection of Technologies:

The methodology began with a kick-off workshop in February, where stakeholders gathered to highlight priority sub-sectors and identify potential technology options within the water and waste sector. This initial meeting set the stage for further detailed assessments by establishing the key focus areas. In March 2024, the 1st stakeholder feedback water technical committee meeting took place, where technologies identified through stakeholder sensitization and desk reviews were further assessed and shortlisted. This meeting involved engaging

[49] ASH affordability case study-Pakistan. Accessed April 4, 2024.

[50] Gender Technical Assessment of Opportunities to Improve Implementation of Plastics and Waste Management in a Ugandan Municipality. Climate investment Funds, June 2021.

stakeholders to gather insights and conducting comprehensive literature reviews, which helped in narrowing down the list of potential technologies. Subsequently, the 1st Technology Roadmap Committee Meeting was held to finalize the scoring criteria for evaluating the shortlisted technologies. During this meeting, the committee developed and agreed on the scoring criteria to assess each technology, ensuring that they reflect the priorities and needs identified earlier. The 2nd Water Technical Committee Meeting then focused on gathering feedback from stakeholders on the shortlisted technologies, discussing financial challenges and opportunities, and considering GESI (Gender Equality and Social Inclusion) aspects for each technology. This meeting aimed to ensure that the final selection of technologies is informed by detailed stakeholder input, financial viability, and inclusive development considerations.

5.1.2 SCORING CRITERIA

For a gendered-based assessment of technologies the criteria was defined by four queries that explored inclusive development, inclusive development and just transition, harmful impacts on women and vulnerable communities, and addressing gender specific needs and promoting social inclusion. Each criteria was granted a score of 1-5, with one denoting the lower end of the spectrum, and five the higher end. The following steps highlight the assessment methodology followed:

1. **The first criteria was defined by the following question:**

    a. Does this technology enhance the quality of life of target communities?

        1. The parameters were adopted from the Pakistan Social & Living Standard Measurement (PSLM 2020-21) document.
        2. The aim was to determine whether the proposed technology would improve the quality of life for women, youth, and vulnerable communities.
        3. This was done by analysing the build-up each technology in light of the socio-economic parameters as mentioned in PSLM (2020-21).
        4. Scoring was restricted to the fulfilment of the following parameters: Improved access to essential services; Economic empowerment; Employment opportunities; Population welfare.

    b. The scoring was based on the following scale:

        1. No significant enhancement,
        2. Limited improvement
        3. Moderate enhancement,
        4. Substantial improvement, and
        5. Significant enhancement with measurable positive impacts

2. **The second criteria was defined by the following question:**

    a. Does this technology contribute to inclusive development and just transition?

        1. A tabulated breakdown of each technology with a focus on the value chain was done with a focus on women, and the vulnerable population.
        2. The aim was to explore the process in which gender inclusivity can be ensured, by delving deep into the role of women in value chain. Support from literature was taken to support the arguments.

b. The scoring was based on the following scale:

1. No inclusivity,
2. Low inclusivity,
3. Medium inclusivity,
4. High inclusivity, and
5. Complete inclusivity (given only if women were included in decision making processes as well).

3. The third criteria was defined by the following question:

a. Does this technology have any harmful impacts on women and/or minorities or youth and children?

1. Both the positive and negative impacts of this technology on the climate were assessed.
2. These were then correlated to the climate-induced health risks being faced by the female/ vulnerable population.

b. The scoring criteria was based on the following scale:

1. High negative impacts,
2. Low negative impacts,
3. No impact,
4. Low positive impacts, and
5. High positive impacts.

4. The fourth criteria was defined by the following question:

a. Does this technology address gender specific needs and promote social equality?

1. This was presented as an average of the scores of the second and third questions.

b. The scoring criteria was based on the following scale:

1. No consideration for inclusivity and social equality,
2. Limited consideration for inclusivity and social equality,
3. Moderate consideration for inclusivity and social equality,
4. Substantial consideration for inclusivity and social equality, and
5. High consideration for inclusivity and social equality.

5.2 Technology Assessment: WASTE SECTOR, THROUGH A GENDER LENS

5.2.1 Composting Technology:

<table>
<tr><td>Composting Technology</td><td colspan="4">Composting is a process that breaks down organic waste (food scraps, yard trimmings) aerobically, by microorganisms, into a nutrient-rich soil amendment called compost. Composting is gaining attention, particularly small-scale composting initiatives at the community level, and are being used in Pakistan to improve cotton production under the Better Cotton Initiative (BCI), 2021[51].</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life[52]</td><td>Impact on Climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>Data from the PSLM survey reveals a concerning trend regarding female participation in this technology. Only 0.01% of women are directly involved in water supply, sanitation, waste management, and remediation activities associated with the technology. This translates to a significant lack of female inclusion in these crucial roles within the sector. The situation extends to professional and scientific fields as well. A mere 0.03% of women are benefiting from this technology in these areas. It is important to note that this data may not be specific suggesting that the impact on women in directly waste-related professions could be even lower.

Taken together, the PSLM data paints a picture of limited female involvement in this technology across various sectors, particularly in socioeconomic and professional aspects. These findings highlight the clear need for initiatives to increase female participation in this field.</td><td><u>Negative Impact of technology</u>

Compost runoff, called leachate, can contaminate soil and water sources if not managed properly. A well-maintained compost pile minimizes leachate production, but it's still a potential concern. More importantly, there has been a movement to divert waste from landfills in order to reduce the negative environmental impact of landfills such as leachate contamination, GHG emissions and space limitation (Slater & Frederickson, 2001, Norbu et al., 2005).

<u>Positive Impact of technology</u>

Nonetheless, in general, net greenhouse gas emissions for landfills tend to be higher than that for composting facilities[53]. There is further reduced exposure to the pollutants as it reduces thenGHG emissions by over 50%[54].
Carbon sequestration will lead to a more congenial environment for the communities (especially women who tend to stay at home) living in the vicinity of the composting site.
This reduces reliance on the landfilling by reducing the burden on landfill site by diverting the organic material from the landfill sites thus cutting down the site's average cost[55].
This is further an easy and sustainable solution for soil fertility by replacing it with harmful artificial fertilizers.</td><td><u>Reduced exposure :</u>

Reduced exposure to the pollutants as it reduces the GHG emissions by over 50%.[56].

Carbon sequestration will lead to a more congenial environment for the communities(especially women who tend to stay at home) living in the vicinity of the composting site .

Sustainable solution with reference to job creation or startup business for women

Easy and sustainable solution for soil fertility by replacing it with harmful artificial fertilizers.</td><td>Increased workload: Traditionally, waste management falls more on women within households. In some cultures, the responsibility of composting could add to their workload, especially if they're responsible for collecting and sorting compostable materials . Composting procedure may compromise their occupational health and working conditions that may lead to mental health and depression[57].

Social norms/ Male pressures
Veiled work with ref to rural female population to be involved in the use of technology . The study on the Gender role in Managing soil fertility via compost use at household level reveals that the main constraint in adoption of compost use and preparation identified in the study lies in the fact that the society is patriarchal and women defer to men's authority and need support of male members of the family. The staggering figure 54% of participant reported that the male head/ husband wont agree to condition for the adoption of the technology[58].</td></tr>
<tr><td>Role of women in value chain</td><td colspan="4">Solid waste management, encompassing storage, collection, transport, and disposal, is vital for environmental health. Yet,within this system lies a hidden powerhouse: women. At the household level, women are the cornerstone of waste management; however when we look beyond the household, the picture becomes concerning. Data on women's involvement in the broader waste management value chain is scarce. This lack of data reflects the reality of a male-dominated formal waste collection sector and the exploitation of informal pickers, often children, by powerful entities. Furthermore, cultural norms can act as a barrier, discouraging women from participating in waste management outside the domestic sphere.

Despite these challenges, women's role remains crucial throughout the entire waste management chain. From managing household waste to potentially working within formal systems, their contributions are essential. Recognizing and empowering women in this sector is key to unlocking its full potential for a more sustainable, equitable, and healthy future.</td></tr>
</table>

[51] Using compost to grow better cotton in Pakistan: A farmer's story. https://blog.cabi.org/2022/06/13/using-compost-to-grow-better-cotton-in-pakistan-a-farmers-story/

[52] PSLM. https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/tables/Table_15.pdf

[56] Hashmi H, Ejaz N, Naushad Z, Ali Z. Impacts of solid waste management in Pakistan: a case study of Rawalpindi city, 2008:685-691. doi:10.2495/WM080701

[57] https://www.researchgate.net/profile/Dhanalakshmi-Dr/publication/281714011_IMPACT_OF_WASTE_MANAGEMENT_TECHNOLOGY_ON_WOMEN_WASTE_WORKERS_IN_COMPOSTING_-_A_CASE_STUDY_OF_ERNAKULAM/links/55f5812d08ae1d9803971751/IMPACT-OF-WASTE-MANAGEMENT-TECHNOLOGY-ON-WOMEN-WASTE-WORKERS-IN-COMPOSTING-A-CASE-STUDY-OF-ERNAKULAM.pdf

[53] https://www.sciencedirect.com/science/article/abs/pii/S0960852408010572

[54] https://drawdown.org/solutions/composting#:~:text=Composting%E2%80%94the%20conversion%20of%20such,by%20more%20than%2050%20percent

[55] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9933540/#:~:text=Composting%20can%20divert%20organic%20waste,gas%20and%20air%20pollutant%20emissions.

[58] https://www.researchgate.net/publication/299587419_Gender_Role_in_Managing_Soil_Fertility_via_Compost_Use_at_Household_Level_Preliminary_Results_from_Dera_Ismail_Khan_Khyber_Pakhtunkhwa

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

[59] https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/tables/Table_15.pdf

5.2.2 Engineered Landfill Technology:

<table>
<tr><td>Engineered Landfill Technology</td><td colspan="4">Engineered landfills are waste dumping sites designed with liners and gas collection systems to capture methane gas produced by decomposing organic waste. This methane can then be used for various purposes like electricity generation or heat production. There is a proposed engineered landfill site in Lakhodair, Punjab, and it is the only site in Pakistan.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>To look at the impacts of this technology through gender lens the available data of PSLM reveals a very bleak picture, if looked at the socio-economic aspect of the technology it is revealed that only 0.01% of the female population that is linked with water supply, sewerage ,waste management and remediation activity. The data for professional , scientific, and technological impacts again paints a very disturbing image with only 0.03% of the females is benefiting but the data reveals the overall picture of the technology sector not specified to be a waste sector technology[59].</td><td><u>Negative Impacts:</u>

Water Contamination: Leachate contamination of water sources can be a major issue, impacting access to clean drinking water. Women and children are often responsible for water collection in households, putting them at greater risk.
The most pressing environmental concern regarding landfills is their release of methane gas. As the organic mass in landfills decomposes, methane gas is released[60], making it one of the most potent greenhouse gases and a huge contributor to climate change[61].
These gases can also contribute to climate change and create smog if left uncontrolled.

<u>Positive Impacts:</u>
Engineered landfills can have a net positive impact on climate if they effectively capture and utilize methane for energy generation. However, proper management and stringent regulations are crucial to minimize fugitive methane emissions and ensure the long-term effectiveness of these systems.</td><td>Improved health: Engineered landfills can reduce health risks associated with open dumps, which often contaminate water sources and air quality. This can lead to better health outcomes for everyone, including women and children who may be more susceptible.

Increased safety: Engineered landfills are typically fenced and controlled environments, reducing the risk of accidents or exposure to harmful materials. This can improve safety for women who may be involved in waste collection or sorting in the informal settings.</td><td>Health Risks:
Landfills can be breeding grounds for pests and release harmful contaminants like methane or leachate into the air and water[62]. This can lead to respiratory problems, developmental issues in children, and even birth defects[63].

Livelihood Impacts: Nearby farms may struggle due to soil or water contamination, impacting food security and livelihoods, especially for women who may be involved in subsistence farming.
Local communities resist the establishment of these sites by arguing the cost of their property depreciating along with their concerns for bad odour, pollution, and birds[64].</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">The process of solid waste management consists of the storage, collection, transportation and final disposal stages in such a way to bring about good environmental sanitation . Women are directly related to solid waste generation in the given household settings. Women are identified as managers of the traditional environment, rehabilitators of the domestic environment, innovators in the use of new appropriate technology in the creation of a clean and healthy domestic environment and finally as protectors and caretakers of the domestic environment. The figures and the available data with reference to women involvement in the value chain sector is non-existent due to the maximum inclusivity of men in this sector and exploitation of the informal sector (waste collectors mainly children) by the powerful few leading this sector. The cultural norms of society also creates great hindrance to women's role in the waste collection sector outside their domestic boundary . The role of women in the value chain remains important from beginning till the end.</td></tr>
</table>

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	1
Does this technology have any harmful impacts on women and /or minorities, youth and children?	2

[60] https://www.edf.org/climate/methane-crucial-opportunity-climate-fight
[61] https://www.saveonenergy.com/land-of-waste/
[62] https://www.saveonenergy.com/resources/landfill-statistics/.
[63] https://link.springer.com/article/10.1007/s11356-022-21578-z#Sec3
[64] http://dx.doi.org/10.29322/IJSRP.8.4.2018.p7662

5.2.3 Waste Segregation:

Waste Segregation Technology	This technology involves separating waste into different categories (organics, paper, plastic, etc.) at the source for efficient recycling, composting, or disposal. Waste Segregation programs are being implemented in Pakistan, such as the "Clean Ambassadors Programme" in Punjab by the Lahore Waste Management Company focused on Students in Schools and Colleges. While some pilot projects exist to promote source separation, widespread segregation at the household level is a challenge due to a lack of awareness and infrastructure for the collection of sorted waste streams.			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	Only 0.01% of women participate directly in water supply, sanitation, waste management, and remediation activities related to this technology. This statistic highlights a significant gap in female representation in these essential roles, indicating a need for increased female involvement and inclusion in these critical sectors. The situation is equally concerning in professional and scientific fields. A mere 0.03% of women are benefiting from this technology in these areas. It's important to note that this data might not be specific to the waste sector of the technology, so the impact on women in waste-related professions could be even lower. The PSLM data reveals a limited role for women in technology across various sectors, particularly in socioeconomic and professional aspects. There's a clear need to increase female participation in this field[65].	**Negative Impact of technology** **Energy consumption:** Processing and sorting facilities for segregated waste use electricity for machinery and lighting. It could contribute to greenhouse gas emissions if it's not from renewable sources. **Limited scope:** Segregation alone doesn't address all aspects of waste and climate change. We still need to focus on waste reduction and composting to minimize overall waste generation and methane emissions from landfills. **Positive Impact of technology** Reduced GHG emissions, the anaerobic decomposition of organic waste leads to methane production a more potent GHG than CO2 so Methane sequestration will lead to economic benefits. Waste segregation at source will reduce the burden on the land fill site.	**Improved Public Health** Due to segregation at the source, there is reduced contact with waste. Thus, preventing accidental exposure to the hazardous waste. Segregation of organic waste at source will lead to involvement of women in making of compost / organic fertilizer through composting / vermicomposting.	Lack of education and knowledge may leave women vulnerable to hazardous waste while segregating it at the source. It will impact the informal waste collection sector, thus leaving many jobless.
Role of Women in Value Chain	Solid waste management involves storage, collection, transportation, and disposal to ensure a clean environment. Within households, women play a critical, yet often invisible, role. However, data on women's involvement in the broader waste management sector is scarce. This lack of data reflects the dominance of men in formal waste collection and the exploitation of informal waste pickers (often children) by powerful entities. Additionally, cultural norms can discourage women from participating in waste management outside the home. Despite these challenges, women's role throughout the entire waste management value chain, from home to disposal remains crucial. Recognizing and empowering women in this sector is essential for a more sustainable and equitable future.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3

[60] https://www.edf.org/climate/methane-crucial-opportunity-climate-fight
[61] https://www.saveonenergy.com/land-of-waste/
[62] https://www.saveonenergy.com/resources/landfill-statistics/.
[63] https://link.springer.com/article/10.1007/s11356-022-21578-z#Sec3
[64] http://dx.doi.org/10.29322/IJSRP.8.4.2018.p7662

5.2.4 Waste Valorisation (Emerging):

Waste Valorisation Technology (Emerging)	Waste valorisation is the process of reusing, recycling or composting waste materials and converting them into more useful products including materials, chemicals, fuels, or other sources of energy. "Waste-to-energy" aspects are becoming more prominent due to the rapid depletion of natural resources and increase in waste generation. Waste valorisation has emerged as a sustainable and visionary solution. Instead of merely disposing of waste, it proposes transforming it into useful resources			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	The PSLM data for the female involved in the Agriculture, forest and fisheries sector is estimated to be 15.49% and that benefiting from waste management sector is 0.01%, with the presence of female population in transportation and storage sector stoops down to 0.01 % with only 0.03 % of women are professionally equipped and are involved in scientific and technological activities and less than 1 % of women are in to household activities or employers or are linked with the service providing sector , this however gives a very alarming scenario for the technology landscape for gender.	**Negative Impact of technology:** The anaerobic digestion of food side-flows is associated with significant GHG emissions, but alternative products (heat and energy) also display a high GHG factor. **Positive Impact of technology:** Valorising waste by using microbes helps in protecting the environment from toxic compounds. Using yeasts for waste valorisation has many benefits, like preserving the ecosystem and producing valuable products like biodiesel. The replacement of diesel with biodiesel will protect the environment by controlling pollution and help the farmer by protecting the agricultural land. In addition to bioenergy production, oleaginous yeast produces several enzymes, like cellulose, lipase, and protease, which are utilized in numerous industries, such as pulp paper, detergent, medicines, food, etc.	Waste valorisation helps women generate extra income by converting plastic into useful items thus turning plastic waste into valuable items for the fashion industry and empowering women. Making women an important part of the value chain from beginning till the end, helping women to overcome their emotional stresses.	Incorrect solid waste management practices can result in severs public health and environmental problems including offensive odours and diseases .
Role of Women in Value Chain	Solid waste management, the intricate dance of storing, collecting, transporting, and disposing of waste, plays a vital role in environmental health. However, within this system lies a group whose contributions often go unnoticed: women. At home, women are the silent orchestra conductors of waste management. They act as: • **Waste Wise Leaders:** Strategically managing household waste to minimize its volume and environmental footprint. • **Domestic Eco-Champions:** Championing sustainable practices to transform waste disposal into a clean and healthy home environment. • **Resourceful Innovators:** Pioneering new technologies and creative solutions to establish a sustainable domestic waste system. • **Guardians of the Family's Well-Being:** Protecting their families by implementing strategies to prevent health risks associated with waste. However, when we shift the lens beyond the household, the picture becomes skewed. Data on women's involvement in the broader waste management value chain is scarce. This lack of data speaks volumes about the reality – a male-dominated formal waste collection sector and the exploitation of informal pickers, often children, by powerful entities. Furthermore, societal norms can act as invisible walls, discouraging women from participating in waste management outside the domestic sphere. Despite these challenges, women's role remains crucial throughout the entire waste management chain. From managing household waste to potentially working within formal systems, their contributions are essential. Recognizing and empowering women in this sector is not just about fairness; it's about unlocking the full potential for a more sustainable, equitable, and healthy future for all.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	5
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	4

5.2.5 Refuse Derived Fuel:

Refused Derived Fuel RDF Technology	A process that converts non-recyclable plastic waste into a fuel source. The plastic is shredded, washed, and processed into a uniform fuel that can be burned for energy in industrial furnaces or power plants. RDF production increased in Punjab when fuel prices were hiked in the past 2-3 years. Cement companies started buying Municipal Solid Waste from Waste management companies to use as fuel in their production processes. D.G. Khan Cement buys 1,000 tons of municipal waste from LWMC to make RDF burnt at the cement plant instead of coal. It emits less harmful emissions than coal which has a considerable impact on mitigating pollution levels[66].			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	Currently, many women, especially in developing countries, spend significant time gathering firewood or other traditional fuels. RDF reduces reliance on such methods, freeing up time for women to pursue education, income-generating activities, or leisure. The FAO estimated that the share of wood energy as a portion of rural energy consumption in the country is 37.52 percent[67].	**Negative Impact of technology** RDF plants emit toxic gases into the environment like dioxins and furans, known as persistent organic pollutants (POP) regulated by Stockholm Convention. They degrade very slowly in environment and mostly effect humans through the food they consume and the air they breathe in. These pollutants can easily affect the humans even from the distance like through wind and ocean currents[68]. **Positive Impact of technology** This process allows for both the simultaneous recovery of thermal energy from the organic part of the alternative fuel and material recycling from the mineral part as a valuable component of the raw material set[69].	Women have mostly tended to the fuel needs of the household for energy purposes for this they are involved in wood collection. Approximately 68% of Pakistan's population depends on firewood as the main source of energy in households. Benefiting from the technology will surely bring positive impact on the female population in terms of carefully involving in themselves in education and sparing time for cottage industry.	RDF facilities can sometimes be located near low-income communities, often with a higher proportion of women. These communities might bear a higher burden of any negative environmental or health impacts.
Role of Women in Value Chain	The application of technology leads to a more sustainable source of energy and follows the novel idea of waste to economy WtE; however, RDF technology offers a double-edged sword for women. While it can improve quality of life by reducing time spent collecting fuel and offering cleaner burning fuel, it can also have negative impacts if not managed properly. To maximize the benefits for women, we need to bridge the gender gap in training and hiring for RDF jobs, ensure women have a voice in decision-making, and make sure facilities are built and run in a way that protects women's health and livelihoods. As per research women and other marginalized communities are found at the lowest strata of the value chain that is at the segregation level starting from the household level by waste separation and selling the paper, plastic, and metal waste in exchange of useful household items like pots or recyclable plastic products.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	2

[66] https://tribune.com.pk/story/1966466/lahore-stands-tall-generating-green-fuel-waste
[67] https://file.pide.org.pk/pdf/PDR/2018/Volume1/73-98.pdf
[68] https://ipen.org/sites/default/files/documents/rdf_esdo_11.23.2023_4th_edit_draft.pdf
[69] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9229322/

5.2.6 Downcycling:

Downcycling Technology	Downcycling means reusing plastic waste to create products of generally lower quality or value compared to the original plastic. Examples include using plastic bottles to make fleece jackets or plastic bags for trash liners. Widely used due to its simplicity and affordability. However, efforts are increasing to promote higher-value plastic recycling processes. The informal sector is mainly responsible for the collection, shredding, and downcycling of waste in Pakistan. People working in the informal sector belong to different socio-demographic and socio-economic groups. Recyclables are collected by males and females of all age groups. They are migrants, minorities, and poor refugees[70].			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	The textile and garment industry employ around 40% percent of the total workforce and according to the Pakistan Institute of Labour Education and Research (PILER), approximately 30% of the workers in this industry are women[71]. While these statistics are for denim, but it uses these downcycled products in its manufacturing line, letting us to assume that this technology is indirectly bring value addition to the female sector.	**Negative Impact of technology** Downcycling plastic isn't a perfect solution. While it keeps waste out of landfills, the process can be energy-intensive, create lower quality products prone to early replacement, and potentially release microplastics. It can also distract from prioritizing true plastic recycling. To maximize the environmental benefits, we need to focus on innovation and responsible management of downcycling facilities. **Positive Impact of technology** Downcycling helps protect the environment by eliminating waste and making new products out of something old that would otherwise end up in a landfill. Materials kept out of waste stream led to multiple benefits such as not requiring additional landfill space, reducing the associated environmental pressure. It also leads to the creation of green jobs and economic opportunities for those recycling and reprocessing these materials into new products[72].	N/A	Downcycling can be a double-edged sword for women. While creating jobs, it might displace them from informal waste picking. Training programs can address this, but gender gaps might make it harder for women to access higher-paying roles. Health risks from poorly managed facilities and unequal opportunities in the downcycled product market are also concerns. To maximize the positive impact, we need to focus on integrating women into formal jobs, bridge the skills gap, enforce safety regulations, and promote fair trade practices.
Role of Women in Value Chain	Women are key players throughout the plastic downcycling chain, but face hurdles. They're already involved in informal waste collection, and downcycling can provide formal jobs in sorting plastic with better pay and safety. However, they're underrepresented in processing plants due to gender bias. Training programs and fair hiring can open doors for their technical skills. Women also bring a consumer's perspective to the table. Their involvement in design and marketing can create downcycled products that resonate with women and promote sustainability. Finally, women can be community champions for downcycling. By empowering them through education and leadership roles, we can drive widespread adoption of these eco-friendly products. The key is to bridge the gender gap in opportunities, ensure fair labour practices, and unleash the power of women as leaders and consumers in the downcycling movement.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	3

[70] https://www.pjoes.com/Role-of-the-Informal-Sector-in-Recycling-r-nWaste-in-Eastern-Lahore,89442,0,2.html

[71] https://gender-works.giz.de/competitions2020/pakistan-inspiring-change-women-in-action-in-the-textile-garment-industry-of-punjab/#:~:text=The%20textile%20and%20garment%20industry%20employ%20around%2040%25%20percent%20of,in%20this%20industry%20are%20women1.

[71] https://doi.org/10.1504/WRSTSD.2019.099377

5.2.7 Non-biodegradable Plastic Pyrolysis (Emerging):

Non-Biodegradable Plastic Pyrolysis Technology (Emerging)	Pyrolysis is a thermochemical process that heats non-biodegradable plastic waste in an oxygen-limited environment. This process can convert the plastic into various products, such as bio-oil (fuel), syngas (combustible gas), or char (charcoal). There might be research or pilot projects exploring non-biodegradable plastic pyrolysis for waste management in Pakistan. Pyrolysis plants that exist in Pakistan are mainly for waste tires and are not focused on non-biodegradable plastic feed.			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	Pakistan's textile and garment industry employs around 45% of the country's total labour force. According to the Pakistan Institute of Labour Education and Research (PILER), about 30% of the workers in the industry are women[73]	**Negative Impact of technology** Pyrolysis facilities are energy intensive. They can also emit carbon monoxide, nitrogen oxides and sulfur dioxide, leading to air and water pollution. These issues have significant financial implications for plant owners who must invest in proper pollution control equipment and regularly monitor emissions[74]. **Positive Impact of technology** In open-loop recycling, also known as downcycling, the quality of the recycled material may be lowered than its original product. However ,this does not imply that the product is lower in value, turning PET bottle into fibre for pillows, printers, car parts can extend the time the new product spends in the system whereas the PET bottle recycled into PET bottle will become waste in less than a year leading to a wastage of all embedded value[75].	The application of the technology will lead to the value addition in the socio-economic gains to the women who are linked with the textile industry. Using pyrolysis to convert plastic to liquid fuel for cooking. Reduced indoor air pollution from the consumption of fossil fuels as women in the third world countries spend most of the time over the stoves. Once exposed, women have a higher chance of contracting lung cancer, chronic obstructive pulmonary disease, and cardiovascular diseases[76]	The process of pyrolysis leads to emissions during the process, causing some serious health concerns due to release of gases like methane & carbon monoxide. Excessive exposure to carbon monoxide reduces the ability of blood to carry oxygen. Various regions are investing in research and development to advance technologies that minimize emissions during pyrolysis. For example, the integration of catalytic converters, advanced filtration systems, and gas-cleaning technologies in pyrolysis plants has shown significant promise in reducing pollutant emissions. These advancements highlight the trend towards adopting cleaner and more efficient production methods.
Role of Women in Value Chain	Indeed, plastic to fuel conversion has the potential to severely limit plastic pollution and to contribute to the circular economy, but industrial scale plastic pyrolysis has not been achieved. As the technology is still in its research phase so its real time impact cannot be gauged, however; if the gender potential is carefully tapped in then they can play a pivotal role in the value chain leading up to policy advocacy. Over the years, women in Pakistan's once thriving textile industry have played a crucial role in supplying Europe and the US with items from denim to towels. Faisalabad the industrial hub of Pakistan hosting 1.3 million textile workers of whom half are women[77] so if given the case gender can be carefully tapped into the value chain of the technology at the production end.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	2

[73] https://aptma.org.pk/overcoming-barriers-to-female-labor-force-participation-flfp-in-pakistan/#:~:text=Pakistan's%20textile%20and%20garment%20industry,women%20(GIZ%20GmbH%20n.d.).

[74] https://www.alfalaval.us/media/stories/sustainability/pyrolysis-of-plastics-challenges-and-solutions/#:~:text=The%20environmental%20impact%20of%20pyrolysis,to%20air%20and%20water%20pollution.

[75] https://bura.brunel.ac.uk/bitstream/2438/18873/1/FullText.pdf

[76] https://www.e-jat.org/journal/view.php?number=132#b1-jat-2022-00157

[77] https://www.theguardian.com/global-development/2023/feb/01/pakistan-textile-industry-crisis-women

5.2.8 Soil Mulching Technology:

Soil Mulching Technology	**Soil Mulching is** applying a layer of organic material (straw, leaves, compost) on the soil surface. Common practice, particularly among small-scale farmers. Different companies like Horticlub and Pak Agro Packaging also provide mulching films all across Pakistan[78].			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	The Pakistan Social and Living Standards 15.49% of the female population is directly or indirectly associated or benefiting from Agriculture, forestry, and fishery sector. In this settings women tend to benefit more from implying mulching than in any other sector mentioned in the PSLM.	**Negative Impact of technology** Impacts the soil pH. Leads to the extinction of some useful herbs. **Positive Impact of technology** Soil erosion and nutrition depletion is the most common threat to food security in developing countries. According to Borst and Woodburn, using a thin layer of 0.6 inches of mulch could reduce the erosion of about 86%. Retains soil moisture and successfully manages weed growth so the use of herbicides is reduced by the growers, so it affects the financial impacts of using herbicides and removal of weeds by human resource.	As evident from the PSLM stats that women linked with agriculture is 15.49% so it will spare the women to enter into more fruitful activities like education , cottage industry leading to economic gains. The Yam farmers in the study area who adopted mulching technology were found to experience a higher output supply than non-adopters, which resulted in a positive and significant effect on their output and net return. Hence, policies targeted at increasing yam output through increasing soil fertility need to include mulching technology as a potentially viable option[79].	Mulching technology, though helpful for agriculture, can have unintended consequences for women. Traditional mulching, often done by women, might be replaced by synthetic mulches or automated techniques, leading to job losses. New technologies could also increase their workload or expose them to harmful chemicals if not handled properly. To address this, we should focus on training women to use the new technology, include them in decision-making about its adoption, prioritize safe handling practices, and explore sustainable alternatives that preserve traditional roles. By ensuring inclusivity, we can make mulching technology a positive force for all in agriculture.
Role of Women in Value Chain	This is an area with potential for growth. By providing training, resources, and opportunities women in Pakistan can become key drivers of a more sustainable and productive agriculture sector. However, if the role of women is carefully channelised then they can play a vital role in value chain from production to marketing , knowledge sharing and leading up to policy advocacy .			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	3

[78] https://horticlub.com.pk/mulch/ https://www.pakagro.com/mulching-film/
[79] https://www.tandfonline.com/doi/abs/10.1080/03031853.2012.695144

5.2.9 Livestock Feeding:

Livestock Feeding Technology	Utilizes agricultural residues like straw or stover as animal feed after proper processing (chopping, treating) to improve digestibility. Livestock feeding is one of the most used practices for managing agricultural waste in Pakistan, especially for ruminant animals like cows and buffaloes. Crop residues are an integral part of the livestock feeding process making 58.8% of the feed.			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	The Pakistan Social and Living Standards 15.49% of the female population is directly or indirectly associated or benefiting from Agriculture, forestry and fishery sector. In this settings women tend to benefit more from the livestock feeding than in any other sector mentioned in the PSLM.	**Positive Impact of technology** The net impact depends on the specific technologies used and how they are managed. Sustainable practices like: Utilizing food waste or agricultural by-products for feed Implementing proper manure management systems (e.g., anaerobic digesters) Optimizing grazing for improved pasture health These practices can significantly mitigate the negative impacts of livestock feeding technology on climate change.	Improved feed conversion. New, super-nutritious feed rations mean livestock need less food to produce the same amount. This directly cuts greenhouse gas emissions from growing feed crops and the livestock while digestion.	Manure management and NOx emissions from manure. Indirect emissions from feed production
Role of Women in Value Chain	In rural settings women work in almost all the areas of agriculture production which includes plantation, transplantation like rice paddy, weeding the fields, harvesting , threshing , cleaning of the grain and the post-harvest tasks of drying and storing . They are also taking care of the livestock. animal husbandry and feeding the livestock women are also involved in some household construction task like clay plastering of the walls roofs and floors using clay and chopped straws, so women tend to play a pivotal role from beginning till the end of the value chain[80].			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	3
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	2
Does this technology address gender specific needs and promotes social equality?	1

[80] https://www.cabidigitallibrary.org/doi/pdf/10.5555/20230444076

5.2.10 Vermicomposting:

Vermicomposting Technology	Utilizes earthworms to convert organic waste (agricultural residues, food scraps) into nutrient-rich vermicompost, a valuable soil amendment. The Lahore Composting Facility is Pakistan's first project introducing composting technology to tackle waste management issues, particularly due to the absence of proper landfill sites. It's a public-private partnership focusing on Municipal Solid Waste Management (MSWM). While vermicomposting research in Pakistan is limited, a Vermicompost Center has been established at the University of Agriculture Faisalabad with support from the Higher Education Commission of Pakistan and Turkish researchers. This center aims to conduct research, produce cost-effective vermicompost, and provide training for on-farm vermicompost production.			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	The Pakistan Social and Living Standards 15.49% of the female population is directly or indirectly associated or benefiting form Agriculture ,forestry and fishery sector . So in this settings women tend to benefit more from the vermicomposting than in any other sector mentioned in the PSLM.	**Negative Impact of technology** Improper composting can release methane and nitrous oxide, potent greenhouse gases worse than CO2. Composting facilities can release unpleasant odors and ammonia, irritating eyes and respiratory systems. Nutrient runoff from compost sites can harm aquatic ecosystems by causing excessive algae growth. Large-scale composting facilities can disrupt natural habitats if not planned and managed carefully. **Positive Impact of technology** The reduced amount of organic material that is mostly food /kitchen waste ending up in the landfill sites thus leading to GHG emissions, this technology employment will lead to a considerable decrease in these emissions thus will have a considerable impact on atmospheric warning. Vermicomposting reduces dependence on chemical fertilizers and can remove NO_x emissions by up to 40% from the BAU scenario.	It serves as a source of income generation, particularly for women managing small-scale vermicomposting units, and contributes to a more sustainable waste disposal system by promoting organic waste management.	Composting itself shouldn't harm women, but its implementation can. Increased workload due to composting duties at home could fall on women if not shared. Similarly, lack of involvement in decision-making might leave them out of discussions about how composting is done in the household. In large-scale facilities, poor management could expose female workers to air pollutants. To avoid this, promote composting education for everyone, encourage shared responsibility at home, and prioritize safety measures for all workers in large facilities.
Role of Women in Value Chain	The role women in Pakistan currently play in the vermicomposting value chain is limited. While vermicomposting holds promise, it's likely still in its early stages of development in the country. However, based on their traditional roles and the potential of vermicomposting women can play a very vital role in the value chain.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	3
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	3

[80] https://www.cabidigitallibrary.org/doi/pdf/10.5555/20230444076

5.2.11 Integrated Biomass Gasification:

Integrated Biomass Gasification Technology	It is a complex thermochemical process that converts biomass into syngas (combustible gas) through gasification. The syngas is then used in a fuel cell to generate electricity. Not currently used for agricultural waste management in Pakistan, as there is little research conducted 23 on this technology in Pakistan[81].			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	Pakistan's Social and Living Standards Measurement (PSLM) survey shows that 15.49% of women are involved in or benefit from the agriculture, forestry, and fishery sector. Within this sector, the PSLM data suggests that IBG could become an area where women see the greatest benefits.	**Negative Impact of technology** Biomass is considered carbon neutral; the gasification process itself releases greenhouse gases. Large-scale biomass use can also lead to deforestation and air pollution. Even the source of biomass matters - unsustainable options can harm soil and food production. **Positive Impact of technology** The gaseous product from gasification, syngas, can be used as fuel gas for heat and electricity generation, and as a feedstock for the production of hydrogen, biofuels, and chemicals.	Reduce GHG emissions. Increased waste management and sustainability. Availability of improved air quality as the process leads to lesser SOx and NOx as the air pollutants, thus contributing to cleaner air. Women tend to be involved in the disposal of the cow dung in the form of cow cake later to be use as fuel thus exposing them to emissions from these dump sites; implementing this technology will reduce this exposure.	This being an emerging technology so it can only be assumed that this may cause land use issues , transportation issues along with the assumption if it can become a sustainable sources of clean energy. Air pollution from inefficient IBG can harm women and children who spend more time indoors.
Role of Women in Value Chain	Women are often responsible for collecting biomass for household fuel. They can be involved in collecting , sorting and even cultivating sustainable biomass feedstock like certain fast-growing grasses or collecting agriculture residues. With proper training, women can be operators and technicians for biomass gasification plants. This can create new job opportunities and promote gender equality in the clean energy sector, which can also lead to entrepreneurship as it progresses. As this is an emerging technology and it is mostly linked with the rural setting so this might take more time and efforts to make women play impactful role at the policy or decision-making level.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	3
Does this technology contribute to inclusive development and just transition?	4
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	4

[81] https://www.sciencedirect.com/science/article/abs/pii/S136403211600277X

5.3 Technology Assessment: WATER SECTOR, THROUGH A GENDER LENS

5.3.1 Drip Irrigtaion Technology:

<table>
<tr><td>Drip Irrigation Technology</td><td colspan="4">A highly sustainable form of irrigation, Ddrip irrigation, also known as trickle irrigation or micro irrigation, is the practice of supplying water gradually to plant roots either via the ground surface or directly to the root zone through a system of valves, pipes, tubing, and emitters. This technique involves using thin tubes to deliver water precisely to the base of the plant[82].</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>Drip irrigation contributes to climate adaptation initiatives by encouraging sustainable water management practices, in accordance with the objectives outlined in the National Water Policy 2018. Additionally, its ability to elevate crop production by 20 to 100% and enhance crop yield presents prospects for improving agricultural productivity amidst fluctuating climate patterns and evolving environmental circumstances. Within the agriculture sector this will empower 68% of the female population[83], employed both directly and indirectly within the agriculture sector. This will not only improve their living conditions, but will further save enough time for them to focus on their health, their children and other economic opportunities.</td><td><u>Negative Impact of Technology</u>

While most of the negative impacts arise from poor management practices; adverse impacts of this technology are usually observed on the abiotic environment, that in turn impacts the climate. Salt accumulation at the perimeter of wetted soil area can trigger root-rot organisms, damaging the plant. Furthermore, it may create pockets of low oxygen in soil that can hamper a health plan growth.

<u>Positive Impact of Technology</u>

The studies from India shows that India has adopted drip irrigation as a solution to tackle its water scarcity issues and bolster agricultural output. A notable example is the state of Karnataka, where this method has been widely deployed, leading to improved crop yields and decreased water usage. Research suggests that in Karnataka, water savings of up to 50% have been achieved through this approach, alongside notable enhancements in crop quality and quantity[84].
Furthermore, this technology aids in reduction of diseases as it limits the extent to which water comes in contact with leaves, stems, and fruits of plants.
This technology further enables the rows between plants to remain dry, while improving access to water, and limits weed growth.
It is cost-efficient, saves water, reduces time spent, and dccreases labor cost.
Water supply efficiency is retained even in uneven ground, and further serves as a barrier in limiting the leaching of water and nutrients below the root zone[85].</td><td>Reports emerging from Nepal indicate that women who utilize solar-powered drip irrigation systems are able to devote 50% less time to irrigation tasks compared to traditional methods[86] of irrigating the fields , thus sparing them some time for other income-generating activities, education, and local or cottage industry .

It was also revealed that before the adoption of this technology only a meager number of households were farming their own vegetables for domestic consumption. However, after the intervention most of the households in the study area produced their own vegetables that ended up in their daily consumption thus adding nutritive value to their food and daily intake.

This technology for Pakistan is a gate-way to ensuring food security to the marginalized communities; and will aid in reducing malnutrition.</td><td>The study in the rural areas of West Nepal highlights the impacts of the drip irrigation technology on gender by stating that this system of irrigation is still largely male dominated with women on the other hand receiving little or no information about the improved agriculture or new technologies[87].</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">This technological intervention has immensely impacted the role of women in the value chain as the study from the rural area of western Nepal revealed an increase in women's share in decision making regarding the purchase of the drip kits, household expenditures, purchase of assets and sale/purchase of agriculture inputs and produce resulted in empowered women[88]. As per this technological intervention a study conducted by IWMI in DI Khan and Tank regions of Pakistan concluded that by introducing new technology and supporting women's training participation can yield significant social impact, as reported by women who feel empowered and valued through such initiatives. This leads to increased acceptance within families and communities of women's roles in farming and mechanical work. Beyond mere skill enhancement and productivity gains, these interventions represent a deliberate effort to reshape gender norms, challenging traditional perceptions of women's capabilities. Encouraging women to embrace technology and boost their income has prompted men to reconsider gender dynamics. Moreover, these interventions have facilitated changes in social norms, such as allowing women safer group travel for training sessions, thus fostering a more inclusive and gender-equal society. Such gender-responsive technological interventions in agriculture and water management signify crucial steps towards transformative change in contexts where directly addressing gender inequality is complex[89].</td></tr>
</table>

[82] https://icid-ciid.org/Knowledge/basic_term/20/Irrigation
[83] https://www.iwmi.cgiar.org/blogs/investing-in-women-is-the-key-to-pakistans-agricultural-growth/
[86] Shrestha, G., Uprety, L., Khadka, M., & Mukherji, A. (2023). Technology for whom? Solar irrigation pumps, women, and smallholders in Nepal
[87] https://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR87.pdf
[88] https://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR87.pdf
[89] https://tribune.com.pk/story/2417839/empowered-by-solar-tech-women-farmers-in-k-p-thrive-with-innovation

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	4
Does this technology have any harmful impacts on women and /or minorities, youth and children?	4
Does this technology address gender specific needs and promotes social equality?	4

5.3.2 Leaky Dam Technology:

<table>
<tr><td>Leaky Dam Technology</td><td colspan="4">Leaky Dams, also known as Large Woody Debris (LWD), are a popular method for managing floods naturally. When placed strategically, they offer a cheap and effective way to lessen flood dangers, especially for entire watersheds. These structures come in many shapes and sizes, with advantages as varied as their designs. They can be simple dams built with local materials or more complex engineered structures. Regardless of their design, they all work by slowing down and storing water in the floodplain. This reduces flood peaks, water speed, and overall flood risk by reconnecting the river to the floodplains.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>Small dams offer a hands on availability of resource, bringing positive impacts as well as improving the quality of life of the population that is residing in water scarce regions[90]. These small dams conserve rainwater, reduce poverty and serves as an affordable solution in contrast to mega hydro-power projects[91]. Small dams can provide a sustainable water resource to 15.49% of the female population who are directly or indirectly linked with the agriculture sector. As per PBS report on Mouza census 2020 the 14% of the rural areas are badly impacted by droughts and 8% by floods thus impacting the quality of life of the agriculture dependent communities[92].</td><td><u>Negative Impact of Technology</u>

The primary limitation of leaky dams is silting, which diminishes the reservoir's capacity to retain water, potentially reducing the amount available for agricultural purposes as well as domestic use[93].

<u>Positive Impact of Technology[94]</u>

Leaky dams are designed to slow down water flows during erratic events thus helping in diverting the flow towards the flood plains. These dams also reduce the flood risk during monsoon flooding.

These dams also help in reducing erosion due to surface runoff .

The design of leaky dams allow the normal flow of water to pass beneath itself and allows the fish with safe passage.</td><td>Leaky dams help reduce flood risk by breaking the water flow during extreme weather events.

These infrastructures help manage and mitigate the devastating impacts of pluvial and fluvial floods on the left behind population that mainly constitutes women, children and elderly.</td><td>The leaky dams have a few limitations but the most prominent one is the problem associated with silting which reduces the reservoir’s water retaining capacity which can ultimately impact the quantity of water discharged for agriculture usage. This may affect the women who are the major stakeholder in the agriculture sector of Pakistan.</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">Pakistan's economy relies heavily on agriculture, with women serving as its backbone. A considerable proportion of the female population, around 68%, are engaged in this sector, contrasting with only 28% of men. Consequently, women play a crucial role in the agricultural value chain by reaping the benefits of leaky dams in the agriculture context. However, their contributions often remain unacknowledged and underestimated, hindered by various barriers such as limited access to resources, knowledge, and decision-making authority[95].</td></tr>
</table>

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	2
Does this technology address gender specific needs and promotes social equality?	2

[90] https://www.dawn.com/news/1455828/the-quality-of-life

[91] https://www.dawn.com/news/1708429/prioritise-small-dams

[92] https://www.pbs.gov.pk/sites/default/files/agriculture/publications/mouza_census_2020/mouza_census_key_findings_report.pdf

[93] https://www.dawn.com/news/118656/depleting-aquifers-in-balochistan

[94] https://www.herefordshire.gov.uk/flooding-2/natural-flood-management-case-studies#:~:text=What%20are%20the%20benefits%3F,slow%20the%20flow%20of%20water.

[95] https://www.iwmi.cgiar.org/blogs/investing-in-women-is-the-key-to-pakistans-agricultural-growth/

5.3.3 IoT Based Solar Pumps and Storage:

<table>
<tr><td>IoT Based Solar Pumps and Storage</td><td colspan="4">Solar pump and storage systems integrate solar energy to operate water pumps and include storage mechanisms to ensure continuous water availability, even when sunlight is scarce. These systems rely on solar panels to capture sunlight and convert it into electricity using photovoltaic cells. Solar water pumps draw water from wells or boreholes, which is then stored in tanks for later use during periods of reduced sunlight. Incorporating internet technology (IoT) enhances automation by enabling the system to activate and deactivate the water pump based on predefined conditions. Sensors, such as humidity gauges and solar panels, allow the system to autonomously adjust watering schedules, minimizing manual intervention, saving time, and improving irrigation efficiency.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>The presence of women at the technical and administrative level is 0.03% in the urban areas of the country as per PSLM data, whereas female participation is non-existent in the rural setting. However, women can benefit from this technology if implemented in its true sense. Then 68%of women in rural settings who are linked with the agriculture sector, will reap its benefits as it will help them save time for other income generating activities as well as education[96].</td><td><u>Negative Impact of Technology</u>
Farmers in hot, arid areas are increasingly adopting affordable solar pumps to irrigate their fields, replacing costly fossil fuels and enhancing crop yields. However, the continuous pumping facilitated by this new technology is leading to the depletion of aquifers worldwide as well as the fluvial ecosystem maintained by the shallow groundwater sources and the wetlands.

<u>Positive Impact of Technology</u>

From an environmental perspective, solar pumping offers notable benefits, in particular a potential decrease in greenhouse gas (GHG) emissions by 95 to 97% per unit of energy utilized for water pumping[97], compared to pumps powered by grid electricity. This decrease is in line with endeavors to combat climate change and diminish carbon emissions, especially when considering the significant CO_2 emissions linked to diesel tube well pumps.</td><td>The substitution of labor-intensive manual irrigation methods has the potential to save time, which could be redirected towards engaging in other income-generating endeavors. This time-saving opportunity may particularly benefit women and children, who can utilize the saved time for activities beyond watering duties[98].</td><td>The classic term ‘Tragedy of the Common’ with exceptional impact by disproportionately affecting the most vulnerable population that are women, children and the elderly due to the over exploitation of the ground water sources[99] for whom the national policies are gender blind who presumably won't be able to avail special benefits like subsidies.</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">Study from India highlights the role of women in the value chain for the technology of using solar powered water pumps for irrigation that led them to the formation of self help groups (SHG) at the community levels and helped them make decisions when it comes to adopting the technology[100]. This emerging integrated technology can impact the significant number of women linked with the agriculture sector in Pakistan as well. Although the presence of the female population, when it comes to the technological participation of women, is alarming at 0.03% in urban settings and 0% in rural settings[101].</td></tr>
</table>

[96] https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/tables/Table_15.pdf

[97] https://e360.yale.edu/features/solar-water-pumps-groundwater-crops#:~:text=Farmers%20in%20hot%2C%20arid%20regions,up%20aquifers%20around%20the%20globe.

[98] https://www.un-igrac.org/sites/default/files/resources/files/The%20benefits%20and%20risks%20of%20solar-powered%20irrigation%20-%20a%20global%20overview.pdf

[99] https://e360.yale.edu/features/solar-water-pumps-groundwater-crops#:~:text=Farmers%20in%20hot%2C%20arid%20regions,up%20aquifers%20around%20the%20globe.

[100] https://reasonstobecheerful.world/solar-based-irrigation-technology-women-farmers-india/

[101] https://www.pbs.gov.pk/sites/default/files/agriculture/publications/mouza_census_2020/mouza_census_key_findings_report.pdf

5.3.4 Micro and Small Hydropower Plants

<table>
<tr><td>Micro and Small Hydropower Plants</td><td colspan="4">Small hydro projects (SHPs) refer to installations with a capacity below 25 MW, further categorized into micro (up to 100 kW) projects[102]. These initiatives utilize the kinetic energy of water flow to drive turbines, resulting in electricity generation. Water is redirected from a stream to a forebay through a canal or intake ditch, with debris filtered out by intake screens. It then travels through a penstock to the turbine and generator unit, where mechanical energy is transformed into electrical energy via magnetic fields. The electricity generated is subsequently transmitted through the transmission system to its designated location.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>Small hydropower projects are typically considered environmentally friendly as they usually don't entail significant deforestation, rehabilitation, or submergence. However, in certain locations, trees might need to be cleared in peripheral areas based on the site layout and project plan. Nonetheless, this is consistently offset by afforestation in the same area or double the land affected[103].
These initiatives impact the quality of life of women and impact them in a more effective way as the PSLM figures state that 15.49% of the women are linked and impacted by such initiatives[104]. 68% of the women who are directly or indirectly linked with agriculture sector that often go unnoticed and unrecognized, are also impacted[105].</td><td><u>Negative Impact of Technology</u>

Small hydroelectric power plants are typically located in the upper regions of river watersheds, causing disruptions to the rivery continuity, and local biodiversity[106].
These SHP often generate small, shallow pools, posing issues such as sedimentation and eutrophication, which can impact water quality and contribute to GHG emissions.
Specifically, a decline in water quality can heighten the risk of waterborne diseases, thereby impacting the health of the population.

Additionally, aquatic species may suffer adverse effects, including

disruptions to migration patterns and alterations in habitat conditions[107].

<u>Positive Impact of Technology</u>

A study in Sri Lanka highlighted the positive impacts of mini hydro power plants over the physical and social envrionment, and further highlighted how reforestation and recycling of waste to produce compost were two important positive impacts of the mini hydro power plants[108].</td><td>As per Forbes study small hydropower plants can provide power to remote areas, improving the life of many. Based on this, women who tend to be responsible for food, energy and water at the household level in the rural areas of Pakistan will no longer have to go to far off areas for fetching and collecting wood at that extensive level.

Moreover it is also stated that the electricity generated by the large-scale dams primarily flows to industries and urban populations, sometimes bypassing local

women and their communities altogether[109].

Beyond other jobs created and catalyzed by these projects, the small hydro power project also creates indirect jobs of the gemstone industry that employs the services of women[110].

Small Hydropower Plants have the potential to significantly enhance the quality of services available to women, particularly in rural and remote areas, by providing electrification[111].

Electricity generated by micro-hydropower (MHP) systems can decrease the time women spend on household chores like gathering fuelwood, thus allowing them more time for education and literacy pursuits. Moreover, access to electricity may enhance other traditionally</td><td>The existing literature did not reveal any negative impact of the technology on women, however in case of any breach in the water reservoir the population living downstream can get affected by washing away the property in its way, and dislocating the population.
However, the world commission on Dams highlighted that around 40-80 million people have been displaced by large dams, whereas the impacts of dams due to the alteration of river flow and its impacts on the freshwater ecosystem that is associated with the construction of these infrastructure has not been estimated[113]. An inference can be drawn from this, whereby the female population dependent on the freshwater ecosystem may become vulnerable.</td></tr>
</table>

[102] https://www.ctc-n.org/sites/default/files/UNFCCC_docs/ref20×01_35.pdf

[103] www.elsevier.com/locat/rser

[106] https://www.frontiersin.org/articles/10.3389/fevo.2021.610325/full

[104] https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/tables/Table_15.pdf

[105] https://www.pbs.gov.pk/sites/default/files/agriculture/publications/mouza_census_2020/mouza_census_key_findings_report.pdf

[107] http://www.esha.be/fileadmin/esha_files/documents/SHERPA/Environmental_Barometer_SHP.pdf

[108] https://www.researchgate.net/profile/Upaka-Rathnayake/publication/323772043_Environmental_and_Social_Impacts_of_Mini-hydropower_Plants-A_Case_Study_from_Sri_Lanka/links/5aab2e2faca272d39cd7ae20/Environmental-and-Social-Impacts-of-Mini-hydropower-Plants-A-Case-Study-from-Sri-Lanka.pdf

[109] https://gaggaalliance.org/women-at-the-frontlines-against-destructive-dams/

[110] https://www.unido.org/sites/default/files/unido-publications/2023-11/How%20Small%20Hydropower%20Empowers%20Women%2C%20Closes%20Gender%20Gaps%20and%20Can%20Do%20More.pdf

[111] https://www.unido.org/sites/default/files/unido-publications/2023-11/How%20Small%20Hydropower%20Empowers%20Women%2C%20Closes%20Gender%20Gaps%20and%20Can%20Do%20More.pdf

[113] https://www.water-alternatives.org/index.php/volume3/v3issue2/80-a3-2-3/file

5.3.4 Micro and Small Hydropower Plants

			female-dominated roles such as shopkeeping or craftwork. Additionally, the provision of public lighting through MHP systems enhances safety in rural areas, a critical concern for women[112].	
Role of Women in Value Chain	Women frequently face exclusion from decision-making processes concerning infrastructure development and governance. Small hydropower (SHP) projects, ranging from a few kilowatts to 10 megawatts, are often decentralized, allowing decisions to be made locally. Implementing a gender approach to SHP development creates a chance for women to participate in decision-making and governance concerning infrastructure development at the grassroots level[114].			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

[115] Ecological impacts of run-of-river hydropower plants - Current status and future prospects on the brink of energy transition 10.1016/j.rser.2021.110833.

[116] Ecological impacts of run-of-river hydropower plants - Current status and future prospects on the brink of energy transition 10.1016/j.rser.2021.110833.

[117] mpact of human intervention and climate change on natural flow regime . Water Resource management 2015;30:685-99 https://link.springer.com/article/10.1007/s11269-015-1185-6

[118] https://www.smec.com/project/karot-hydropower-project/

[119] https://www.iwmi.cgiar.org/blogs/investing-in-women-is-the-key-to-pakistans-agricultural-growth/

5.3.5 Runoff River Plants:

Runoff River Plants	Run-of-the-river hydroelectricity, commonly referred to as ROR, is a method of hydroelectric power generation distinguished by its minimal or absent water storage. Unlike conventional hydroelectric plants that depend on reservoirs for water storage and regulation, ROR facilities typically lack significant storage capacity, with any storage being termed as pondage. The concept of ROR hydroelectricity has garnered interest due to its diminished environmental footprint, potentially reduced development expenses compared to large-scale hydro projects, and its suitability for various sites. Although it is an established technology, ongoing advancements are continuously enhancing its efficiency and environmental sustainability.			
Impact	**Impact on Quality of Life**	**Impact on climate**	**Positive Impacts on Female Population**	**Negative Impacts on Female Population**
	These structures play a vital role in regulating water flow throughout different seasons. Additionally, hydropower plants are indispensable for economic decarbonization efforts and for fulfilling the energy needs of societies.[115]	**Negative Impact of Technology** These initiatives may affect the natural flow regimes of the river.[116] Extensive intervention/exploitation of the resource may impair the fluvial ecosystem and its integrity.[117] **Positive Impact of Technology** Runoff river plant technology positively impacts the climate as is the case of Korat runoff river hydro power plant which is impacting the environment through an annual reduction of 3.5 million metric tons of carbon emissions and conserving approximately 1.4 million tons of standard coal equivalent per year[118].	As these intervention play crucial role in providing certain ecosystem services as food in the form of fish and water for irrigation then it can be inferred that it directly brings positive impacts on the life and livelihood of the female population 68% of them in rural settings are linked with the agriculture sector.[119]	The negative impacts may include food insecurities resulting due to the alterations in the river flow and impacting fluvial ecosystems and the fish habitat. This may lead to food insecurities for the population relying on fish for food and livelihood, with the discharged water affecting the agriculture activity downstream.[106]
Role of Women in Value Chain[120]	Women exhibit low involvement in non-traditional sectors like energy. A 2018 foundational study by the Women in Energy Network of Pakistan reveals that women represent merely 4% of the workforce across 9 power utilities (comprising both public and private distribution, transmission, and generation companies) in Pakistan. Within the engineering sphere, women account for just 4% of total recruits, despite comprising 25% of enrolled students at BSc/MSc levels. Technical roles within the 3 Independent Power Producers examined in the study are filled by only 3% women employees. The Water and Power Development Authority employs 6% women, with 3.3% holding technical positions. In distribution companies (DISCOs), women constitute only 2% of the workforce, and of these, 4% occupy technical positions. At the National Transmission and Dispatch Company (NTDC), a mere 3% of female employees are in technical roles as engineers. The role of women can be enhanced in this sector if thoroughly involved in the decision-making process.			

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

[120] Gender Divide of Energy.https://pakngos.com.pk/gender-divide-of-energy/

5.3.6 AI Integrated GIS and Remote Sensing for Water Management

<table>
<tr><td>AI Integrated GIS and RS for Water Management</td><td colspan="3">Geographic Information Systems (GIS) are pivotal in water resource management, facilitating spatial analysis and visualization of data. GIS also analyzes water supply scenarios, aiding in demand forecasting. These capabilities inform effective water resource management, promoting sustainability[121]. Remote sensing (RS) and Geographic Information Systems (GIS) currently provide crucial data on water sources, flow patterns, and environmental impacts, aiding in the selection of hydropower plant locations and water availability prediction. AI presents an opportunity to enhance this process by swiftly analyzing vast amounts of RS data, automating tasks, and identifying trends. Additionally, AI can analyze real-time sensor data from hydropower plants, facilitating proactive maintenance and problem detection. AI-driven scenario modeling can simulate future scenarios like droughts, aiding in long-term water security planning. Integrating AI with RS and GIS in Pakistan offers benefits such as increased efficiency in water usage, informed decision-making through real-time data, and long-term planning for sustainable hydropower generation.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Overall Impact onfemale Population</td></tr>
<tr><td>Data from Coursera, as of 2022, indicates a lack of parity in enrollment across all skill categories except for teaching and mentoring courses. In technology-related skills such as technological literacy (43.7% parity) and AI and big data (33.7%), which are identified among the top 10 skills expected to grow, enrollment falls below 50% parity, with progress advancing slowly. Gender gaps tend to widen across all skill categories as proficiency levels increase. Nonetheless, when women do enroll, they often achieve higher proficiency levels across the studied skill categories in a shorter time compared to men.</td><td><u>Negative Impact of Technology</u>

Utilizing AI in the context of climate change presents fewer and milder ethical concerns (Tsamados et al., 2020) compared to its application in fields like healthcare and criminal justice, where personal data and human-facing decisions are central to operations.[122]

<u>Positive Impact of Technology</u>

AI operated hydroelectric power plants ensure effective use of water resources to promote decarbonized society.[123]

Hydropower helps in avoiding emissions equivalent to approximately 9% of the global annual CO2 emissions[124].
Impact of AI on GHG emissions
Leveraging the problem-solving capabilities of AI in the context of climate change could offer significant benefits by aiding in the comprehension of the issue and facilitating effective responses[125].</td><td>The World Economic Forum underscores a significant gap, indicating that women make up just 22% of the global workforce in AI expertise.This disparity becomes even more evident in the wider domain of AI and machine learning, where only 22% of professionals are women[126]. However if the AI potential is carefully tapped then it may lead to the following impact on women.

1. Increased Access to Opportunities: Streamlining operations with AI can create new job roles accessible to women by reducing physical labor requirements.
2. Skill Development and Training: Implementing AI may necessitate training, empowering women with technical skills for better employability and advancement.
3. Improved Work-Life Balance: AI optimization can lead to more efficient workflows, reducing workloads and enabling women to balance professional and personal responsibilities effectively.

4. Reduced Gender Bias: AI-driven decision-making can mitigate gender bias in the workplace by relying on objective criteria, potentially fostering a fairer work environment.
5. Representation in STEM Fields: Highlighting women's participation in AI-driven technologies can inspire more females to pursue careers in STEM, fostering diversity in the hydropower industry.</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="3">The World Bank report clearly highlights the global share of women in hydropower sector as 29% women holding key positions at senior level management, 24% at the Mid level management and only 19% holding the key positions at the Board of Directors level, however it also brings attention to the fact that 1 in 4 positions in the hydropower industry is held by women[127]. So, inferring from this data this technology highlights the role women can play in the value chain of the technology if implemented in its true sense. From the benefits highlighted we can assume that the time this technology will save will help women capacitate themselves in the weaker areas for better inputs.</td></tr>
</table>

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

[124] https://www.iea.org/events/iea-at-cop27-the-role-of-hydropower-in-achieving-climate-resilience
[125] https://doi.org/10.1007/s00146-021-01294-x
[127] https://documents1.worldbank.org/curated/en/099101223160549405/pdf/P1754820142bfa0d10bb3b00f5813ff1814.pdf

5.3.7 Rainwater Harvesting Technology

<table>
<tr><td>Rainwater Harvesting Technology</td><td colspan="4">Rainwater Harvesting is a sustainable method that collects rainwater from rooftops and stores it in tanks for later use, and helps reduce reliance on freshwater sources. It is a well-established technology in Pakistan with CDA having recently approved a new policy that requires all residential and commercial buildings to install rainwater harvesting systems on their premises to conserve water. This system further aids in water conservation and mitigate water scarcity issues. A network of rainwater harvesting systems has been developed by PCRWR, spreading over 26,000 km^2 in the Cholistan desert by developing specially designed 110 reservoirs with a water storage capacity of 440 million gallons[128].</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life[129]</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>15.49% of the females linked with agriculture will be positively impacted as this is a cost saving activity. Women can use the water collected to feed their livestock, therefore reducing the time it takes them to collect water from far-flung areas. It is a safe activity that reduces the incidences of domestic violence faced by women in water-collection activities.
However, 0.01% of the women involved in the water supply sector have the least impact in terms of the technology implications.</td><td><u>Negative Impact of Technology</u>

Harvested rainwater may carry with itself airborne pollutants if not filtered that can adversely affect the health of the individuals. Furthermore, if rainwater is not stored carefully it can serve as a breeding ground for mosquitoes, increasing the prevalence of dengue and malaria, and contributing to the burden of disease.

<u>Positive Impact of Technology</u>

Rainwater harvesting offers a double win. It not only provides a reliable alternative water source as existing reserves dwindle and populations rise, but also reduces the burden of household water collection, particularly for women. With depleting ground water sources in terms of quality and quantity; rain water harvesting technique offers an easy and handy solution to these concerns[130].

Further positive impacts can be observed in the following ways:

1. Provision of rainwater for domestic use.
2. Reduced surface runoff and lesser urban flooding.
3. Helps overcome water scarcity issues in water stressed areas.
4. Self-sufficient and ensures protection of water resources.
5. Rain harvesting is inexpensive and sustainable. It provides high-quality water, and excess water can be diverted to storage areas to feed groundwater.</td><td>Rainwater harvesting positively impacts rural women's lives as it reduces their daily task to gather water from long distances for drinking and food preparation purposes. Women farmers collect rainwater and utilize it for kitchen gardening for their family's consumption. This also empowers women economically.
Rainwater conservation by women has had excellent impacts on food security and saves water in order to reduce flooding in downstream areas. Extreme climatic events and prolonged droughts can be coped efficiently with this project and, as a result, reducing the demand on other natural reserves of water.

This technology further reduces the prevalence of water-borne diseases and hunger, with the promotion of adaptation to climatic conditions[131].

Roof top rainwater harvesting for schools, especially girl's schools, play a vital role by reducing the number of girl student's drop out cases. Lack of availability of water during menstruation and sanitation and hygienic needs of female students can be effectively catered through this technology, with students spending most of their time in the schools so that their needs can be effectively catered[132].</td><td>If the harvested rain water is not stored according to the prescribed standards then there are chances that it may lead to the negative impacts by creating favorable conditions for certain vector and waterborne diseases like;

Mosquito breeding: If the storage systems are not properly sealed, they can become a breeding ground for mosquitoes.

Water pollution: If the rainwater is contaminated by pollutants on the roof or in the catchment area, it can become a source of water pollution.</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">Studies have shown that rainwater harvesting empowers women by alleviating the burden of water collection, freeing up time for education and income generation. For an estimated 51% of the population living in areas impacted by desertification, rainwater harvesting can be a potential solution . Rainwater harvesting provides a more reliable water source closer to homes, particularly beneficial for women and children[133].</td></tr>
</table>

[128] https://pcrwr.gov.pk/rainwater-harvesting/

[129] https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/tables/Table_15.pdf

[130] https://cscr.pk/explore/themes/energy-environment/water-crisis-and-rainwater-harvesting-prospects-in-pakistan/

[131] https://womengenderclimate.org/gjc_solutions/rainwater-harvesting-and-conservation-training-for-women-farmers/#:~:text=This%20project%20positively%20impacts%20on,This%20also%20empowers%20women%20economically

[132] https://www.nestle.pk/stories/harvesting-rainwater-conserving-water-right-sanitation-schoolgirls

[133] https://www.iied.org/sites/default/files/pdfs/migrate/10105IIED.pdf

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	4
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

5.3.8 Chlorination

<table>
<tr><td>Chlorination</td><td colspan="4">Chlorination is a widely used disinfection method that involves adding chlorine to the water to kill harmful bacteria and pathogens. Chlorination helps mitigate health issues associated with water by killing all the bacteria and pathogens in it. Chlorination is the most commonly used water treatment method in Pakistan[134].</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>As per the PSLM data women involved in water supply, sewerage, waste management and remediation activities is no more than 0.01%. However, if we look at the overall impact of the technology in the health sector, it becomes clear that in Pakistan, waterborne diseases account for 80% of all diseases and 33% of deaths. In addition, there is a high national expenditure of Pakistani rupee (PKR) 112 billion per annum due to hygiene related illness; it includes disease caused by unsafe water and poor sanitation.[135] If this much of the national expenditure is invested in WASH sector then it can improve the overall health of the population[136].
According to DALYs, 71.75% of the risk factor associated with diarrhea is linked to the use of unsafe water, resulting in 2.38% of total DALYs and 2.39% of total deaths attributed to diarrheal disease. However, these outcomes could be prevented through the meticulous adoption of technology[137].</td><td><u>Negative Impact of Technology:</u>
Chlorine in molecular and in compound forms is known to pose many health hazards. Hypochlorite addition to soil can increase chlorine/chloride concentration, which can be fatal to plant species if exposed. When chlorine compounds reach the sewer/drainage system and are exposed to aqueous media such as wastewater, many disinfection by-products (DBPs) can be formed depending on the concentrations of natural organic matter, inorganics, and anthropogenic pollutants present[138].

<u>Positive Impact of Technology[139]:</u>
Chlorination eliminates almost all the harmful microorganisms from the water and retains the water quality and protects it from recontamination for a longer period of time.

It is cost effective as a small quantity of chlorine can ensure safe water for an entire city.

It has an easy application to any water source and does not require expensive techniques, machines or processes.</td><td>Chlorination is a very hands-on technology, allowing even rural women to add chlorine in the water storage tanks locally to improve the overall health of the population[140].
Passive chlorination at the point of collection could be an effective and scalable strategy in low-income urban settings for reducing child diarrhoea and for achieving global progress towards Sustainable Development Goal 6.1 to attain universal access to safe and affordable drinking water. Targeting a low chlorine residual (<0·5 ppm) in treated water can increase taste acceptability of chlorinated drinking water while still reducing the risk of diarrhoea[141].</td><td>Although chlorination technology is widely practiced for its immediate effects of disinfection, it comes with some negative burden on human health. The regular consumption of chlorinated water leads to the harmful effects on human health developed due to THM(Trihalomethane) which include chloroform, regular consumption may lead to the risk of food allergies, asthma, bladder and rectal cancers, various congenital anomalies other than poor smell and taste[142].</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">Global water access data have established that women and girls are primarily responsible for water fetching,but less research has explicitly discussed the highly gendered household allocation of water treatment responsibilities. Keeping data in mind the role of women in water purification for household use is very vital so they are playing a pivotal role in the value chain, thus learned and trained women can help mentoring other women in the community on how to use the technology for their benefits. The historical public health benefits of centrally treated piped water are often cited as evidence of the importance of safe water interventions[143].</td></tr>
</table>

[136] https://doi.org/10.1016/j.amsu.2022.104709

[137] Institute for Health Metrics and Evaluation (IHME). GBD Compare; 2019. Retrieved from: https://vizhub.healthdata.org/gbd-compare/ (Accessed on 16 May 2024).

[138] https://pubmed.ncbi.nlm.nih.gov/35091954/#:~:text=Chlorine%20in%20molecular%20and%20in,to%20plant%20species%20if%20exposed.

[139] https://etrlabs.com/the-benefits-of-water-chlorination/

[143] https://ehp.niehs.nih.gov/doi/full/10.1289/EHP10839

[134] https://pcrwr.gov.pk/wp-content/uploads/2021/08/Water-Treatment_final.pdf

[135] https://www.sciencedirect.com/science/article/pii/S2049080122014698#:~:text=In%20Pakistan%2C%20waterborne%20diseases%20account,and%20poor%20sanitation%20%5B22%5D.

[140] https://www.ircwash.org/sites/default/files/245.11-95IM-18921.pdf

[141] https://www.ircwash.org/sites/default/files/245.11-95IM-18921.pdf

[142] https://sensorex.com/the-effects-of-chlorine-in-water/#Rectal_and_bladder_cancer

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community?	2
Does this technology contribute to inclusive development and just transition?	3
Does this technology have any harmful impacts on women and /or minorities, youth and children?	3
Does this technology address gender specific needs and promotes social equality?	3

5.3.9 Groundwater Aquifer Recharge Using Wastewater

<table>
<tr><td>Groundwater Aquifer Recharge using Wastewater</td><td colspan="4">Groundwater recharge with reclaimed wastewater is an innovative water management technique that utilizes treated wastewater to replenish underground aquifers. Using treated wastewater for recharge reduces the reliance on freshwater sources like rivers and lakes for non-potable uses like irrigation or industrial processes. As the treated wastewater percolates through the soil and rock layers (vadose zone) before reaching the aquifer, it undergoes further natural purification. This additional filtration helps remove contaminants and improves water quality.</td></tr>
<tr><td rowspan="2">Impact</td><td>Impact on Quality of Life</td><td>Impact on climate</td><td>Positive Impacts on Female Population</td><td>Negative Impacts on Female Population</td></tr>
<tr><td>As per DALYs the risk factor involved in Diarrhea is 71.75% attributed to the utilization of unsafe water leading to 2.38% of the total DALYs and 2.39% of total Deaths are due to the diarrheal disease. However, this can be avoided by the careful implementation of the technology[81].</td><td><u>Negative Impact of Technology</u>
Waste water if improperly treated and recharged can leach into the ground, contaminating aquifers, and the regional soil ecosystems. Metal accumulation in food crops[144]. The greenhouse gas emissions from the wastewater sector are identified and carbon footprint quantification tools, such as reliable models and emission factors are compared. The direct process emissions can contribute to over 60% of the carbon footprint in wastewater treatment plants[145], while around 30% of the carbon footprint is due to energy-related indirect emissions. Therefore, greenhouse gas mitigation via process optimization and energy usage in wastewater treatment plants are comprehensively described[146].

<u>Positive Impact of Technology</u>

Increased access to groundwater offers a double win for smallholder farmers

Boosted incomes and resilience: Farmers with groundwater can diversify their crops, leading to a 50-100% increase in yields and a more stable income. This also improves their ability to withstand droughts.

Sustainable water use: By adopting better irrigation methods, farmers can significantly reduce water waste, lowering energy consumption and the environmental impact of groundwater extraction.</td><td>Women, often fulfilling domestic roles, rely on groundwater for various purposes, necessitating frequent journeys from their homes to its source. Yet, the provision of a sustainable water source could alleviate this challenge, reducing the need for multiple daily trips[147].</td><td>A study carried out in Greece highlighted that if the treatment technology is not implemented correctly, there could be adverse consequences, as highlighted by Blokker, Smeets, and Medema (2018). Sensitivity analysis underscored the significance of contamination concentration on ingested doses. Moreover, their findings emphasized how the choice of dose-response greatly influenced infection risk. Additionally, the modeled probability of contamination detection stood at approximately 25%. Contaminants, as estimated, could potentially migrate through the water distribution system and ultimately reach household taps and

showers, posing significant health risks[148]</td></tr>
<tr><td>Role of Women in Value Chain</td><td colspan="4">Women play a vital role in household and community-based water recycling initiatives, particularly in utilizing greywater from kitchens, laundry, and bathing for farming purposes in areas where freshwater is scarce or costly. Affordable treatment options can be implemented for individual households or multiple residences. Examples from Jordan, Palestine, and Lebanon demonstrate the value of stakeholder involvement, especially by women, in designing local treatment and reuse systems. Women, often responsible for household water management, reported that reclaimed water improved food security and reduced the need to fetch water from polluted sources, leading to significant time savings. Community-supported greywater recovery systems for gardening enabled communities to reduce food expenses and generate income by selling surplus produce. Studies from Palestine and India highlight the importance of empowering women and addressing their practical and strategic needs to foster acceptance of treated wastewater reuse. In India, an intervention supported women</td></tr>
<tr><td></td><td colspan="4">farmers in utilizing recycled greywater for vegetable cultivation during the dry season, reducing water transport costs and enhancing their income.
As per a blog by World Bank women in rural communities of Rehmatabad, Yezman and Ather are acting as ‘Herald of Change’ and playing their pivotal role in Women In Water Initiative (WiWi) documented the role of women in RWS planning and decision making, community development , entrepreneurship ,and Operation and maintenance[149].</td></tr>
</table>

[144] https://www.sciencedirect.com/science/article/pii/S2468584421000945#:~:text=Salinity%20and%20metals,load%20of%20salts%20in%20wastewater.

[145] https://www.sciencedirect.com/topics/engineering/wastewater-treatment-plant

[145] https://www.sciencedirect.com/science/article/pii/S1364032123004951#:~:text=It%20is%20estimated%20that%20wastewater,2030%20%5B2%2C3%5D.

[147] https://doi.org/10.1016/j.gsd.2017.11.007

[148] https://doi.org/10.1002/wer.1157

[149] https://blogs.worldbank.org/en/water/women-in-water-in-pakistan-shows-t he-way

Technological assessment criteria	Score
Does this technology enhance the quality of life in the target community ?	2
Does this technology contribute to inclusive development and just transition?	2
Does this technology have any harmful impacts on women and /or minorities, youth and children?	1
Does this technology address gender specific needs and promotes social equality?	2

6. MAXIMIZING GENDER IMPACT: RECOMMENDATIONS FOR TECHNOLOGY ASSESSMENT

6.1 WASTE SECTOR

Pakistan's waste sector holds promising opportunities for technological advancements that promote gender equality. The table below presents a shortlist of the top 5 higher potential technologies, that had a score of greater than 10, as scored via the gender-focused assessment. These technologies were carefully selected based on their potential to create a more inclusive waste management system, empowering both men and women in the sector:

Rank	High Potential Technologies	Score (out of 20)
1	Waste Valorization	17
2	Integrated Biomass Gasification	15
3	Waste Segregation	13
4	Vermicomposting	12
5	Composting	11
	Downcycling	
	Soil Mulching	

Pakistan, therefore, holds the potential to revolutionize its waste sector, and to promote gender equality in this domain. Certain considerations, and recommendations need to be taken into account to ensure that this sector serves as a platform to alleviate poverty, to steer towards a cleaner Pakistan, ultimately promoting sustainability.

Primarily, in the waste sector, there is a need to integrate and enhance skills training and capacity building of the workers. These can be achieved via the development of gender-specific training programs that accommodate to the existing skills and comfort levels of women. There is further a need to enhance and ensure inclusivity in operations and maintenance by arming the female workforce with the technical skills needed to operate and maintain waste management technologies, not just basic sorting tasks. But most importantly, the gender potential of these technologies can only be maximized once women are included throughout the value, particularly in the form of leadership roles being held by women.

Inclusive work practices and safety is another aspect that needs to be ensured. Provision of safe work environments is a basic human right, and in this sector, this includes the implementation of safety protocols, along with the provision of necessary personal protective equipment (PPE) for all waste workers, regardless of gender. There is further a need to combat stigma, and explore flexible work schedules or childcare support to allow women with childcare responsibilities to participate actively, and stress-free in the workforce. Advocacy for equal pay is an integral step in ensuring gender inclusivity is kept into consideration during the implementation of these technologies. Women need to be further equipped with financial literacy skills to handle their earnings and finances, and to take the step towards financial independence. But the perhaps the integral consideration stems from the urgency to prioritize user-friendly designs, for the new technologies, that are accessible and safe for all genders. The technologies need to ensure that they are designed in a way that minimizes physical strain, with safeguard set in place that ensure safety and protection of the female workforce.

A long road ahead, but one that will be integral to a more inclusive and equitable waste management system that empowers both men and women, fostering a more sustainable future for the nation.

6.2 WATER SECTOR

Pakistan faces challenges in its water sector, but also holds immense potential for technological advancements that address gender disparity. The table below presents a shortlist of the top 53 higher potential technologies, that had a score of greater than 10, as scored via the gender-focused assessment. These shortlisted solutions aim to improve water access, management, and sanitation, specifically considering the needs and opportunities for both women and men in Pakistani communities.

Rank	High Potential Technologies	Score (out of 20)
1	Drip Irrigation	16
2	Micro and Small Hydropower Plants	13
	IoT Based Solar Pumps and Storage	
	Rainwater Harvesting Technology	
3	Chlorination	11
	Soil Mulching	

The shortlisted water technologies, hold immense potential for Pakistan. However, to ensure these advancements truly empower both genders, a multi-faceted approach is necessary. Primarily there is a need to lighten the burden and address the time-consuming and often physically demanding task of water collection, traditionally borne by women and girls. Technologies like solar pumps and rainwater harvesting can significantly reduce this burden by providing readily available water sources closer to homes. Additionally, ensuring water access points are conveniently located and accessible for everyone, especially those responsible for carrying heavy water containers, is essential.

Promoting women's participation in water management is key. Providing training programs on operating and maintaining water technologies like chlorination systems or irrigation techniques equips women with valuable skills. Furthermore, encouraging women's active participation in water management committees at the community level empowers them to be decision-makers in water pricing, allocation, and maintenance.

As with the waste technologies, financial empowerment paves the way for women's long-term involvement in the water sector. Facilitating access to microloans for women entrepreneurs allows them to establish small businesses providing water-related services or manage community water kiosks. Furthermore, establishing water user associations with fair representation for women ensures they have a say in the sector's financial sustainability.

Finally, promoting hygiene education and awareness campaigns is crucial. These campaigns should target both men and women, emphasizing proper sanitation practices and the importance of safe water usage. Additionally, addressing cultural biases that might prevent women from participating fully in water management activities through community awareness programs fosters a more inclusive environment in the sector.

By implementing these recommendations alongside the chosen technologies, Pakistan can create a water sector that empowers women and men equally. This will lead to improved water access, management, and sanitation, fostering a more sustainable and healthy future for all communities.