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Integrating Carbon Handprint Assessments into City Planning for Promoting Urban Sustainable Growth

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Abstract - *This article explores how the carbon handprint approach can be implemented in urban planning, specifically focusing on exercising the carbon handprint at the city and regional levels. It aims to minimize the carbon footprint and support environmentally friendly practices as much as possible. The Espoo, Finland case study emphasizes four key components as pivotal to the research: creating environments conducive to climate-friendly operations, allowing local access to city-owned resources, encouraging the development of innovative urban projects, and building a sustainable business ecosystem. It also assesses the contribution of renewables and sustainable infrastructure, such as electric vehicle systems, to increase the carbon handprint. These findings illustrate the capacity of cities to do their share in mitigating climate change through deliberate actions that not only minimize the harmful effects but can also lead to scalable, low-enrichment pathways. This study informs and advises policymakers, planners, and regional authorities, presenting a strategic framework for the adoption of a carbon handprint mechanism to uplift climate-aligned urban settings when intertwined with sustainability and resilience plans and policies.*

Key Words: **Carbon handprint, Carbon footprint, Urban Planning, Sustainable Growth, Renewable Energy, Climate Change Mitigation**

1. INTRODUCTION

Imagination our cities not only as contributors to climate change but as the locations where positive environmental change is created. Right now, cities, accounting for more than 75% of global resource consumption and a big part of greenhouse gases as well, are still major contributors to climate change. In conclusion, with 68% of the world's population expected to live in cities by 2050, these initiatives have never been more essential to ensure sustainable urban living. This is especially the case for countries such as India, which is the third-largest greenhouse gas emitter in the world and where metropolitan areas deal with high per capita emissions.

What if we could change the narrative? Which is where the carbon handprint comes in. This powerful counterpart to the better-known carbon footprint comes to us from the mind of Gregory Norris [4]. While a carbon footprint focuses on the amount of greenhouse gases we release into the atmosphere, a carbon handprint represents the positive steps we take toward the environment. Consider doing not only less harm, but also doing good for our planet.

This work investigates how cities can maximize their positive impact with the help of the strategies to uplift carbon handprint, laying a new paradigm for the field of urban planning. It answers the urgent call for cities not only to mitigate their negative carbon footprint, but to also support scalable, low-carbon solutions. Focusing on carbon handprints — initiatives such as energy-efficient buildings, renewable energy sources, and green infrastructure — allows cities to significantly ramp up their climate-impactful growth. The overall aim is to design and test strategies for producing and integrating carbon handprint assessments into urban plans, in order to provide policymakers and urban planners with relevant information to design climate-positive urban systems around the world. It's creating cities that don't just sustain, but make our planet healthier.

Table -1: Table showing the basic difference in carbon footprint and handprint aspects

Aspect	Carbon Footprint	Carbon Handprint
Definition	Total greenhouse gas emissions caused by an activity, product, or organization.	Positive environmental impact by reducing or avoiding carbon emissions.
Focus	Measures the negative environmental impact.	Measures the positive environmental impact or solutions to reduce harm.
Purpose	Highlights the amount of carbon dioxide (CO2) released into the atmosphere.	Focuses on actions that reduce CO2 emissions or increase carbon capture.
Approach	Tracks and calculates emissions from production, transportation, energy use, etc.	Tracks activities that mitigate emissions, such as sustainable practices or renewable energy.

Common Examples	Emissions from transportation, manufacturing, energy consumption, etc.	Using renewable energy, sustainable construction, reforestation, etc.
Goal	To reduce the amount of carbon emissions.	To increase the positive impact by reducing environmental harm.
Measure ment	Calculated in units of CO2 equivalent (CO2e).	Represents CO2e avoided or reduced due to positive actions.

2. LITERATURE REVIEW

2.1 Handprint Concept

The handprint concept was introduced to measure and communicate the positive changes and beneficial impacts of actions, in contrast to the footprint which measures negative impacts. A handprint can be created by preventing or avoiding negative impacts (footprints) or by creating positive benefits [1]. Handprints can take place anywhere in the world and be composed of multiple small impact reductions. Handprint thinking focuses on the good we do, unlimited potential, recovering/restoring, influencing, educating or inspiring, appreciating/celebrating, advocating protection, and entrepreneurism according to K. Behm et. Al [1]. This contrasts with footprint thinking, which focuses on the harm we do, limited resources, reducing/reusing/recycling, admonishing, calculating, and resisting destruction.

2.2 Handprint Methodology

Handprint and footprint methodologies utilize the same LCA-based approaches and frameworks, considering the full value chain. Some key guidelines and concepts related to handprint methodology include:

- Handprint calculation according to SHINE and G. Norris.
- Avoided emissions guidelines for the chemical industry by WBCSD and ICCA.
- The GHG Protocol
- Carbon footprint of products

However, common and widely accepted calculation guidelines for handprints, especially at the city or regional level, are still missing.

2.3 Carbon Handprint Approach for Cities and Regions

The carbon handprint approach is introduced as a complementary measure to the traditional carbon footprint. While the carbon footprint quantifies the total GHG emissions of a city, the carbon handprint focuses on the positive climate impacts that a city can facilitate through its actions, products, and services [2]. This approach allows cities to communicate their contributions to reducing the carbon footprints of other entities, such as residents and businesses. According to Grönman et. al [2], three main mechanisms are considered through which cities can achieve a carbon handprint:

1. Ownership: Cities can own and operate projects that reduce emissions for others.
2. Operating Environment: By creating a supportive environment for low-carbon initiatives, cities can enable others to reduce their footprints.
3. Innovative Solutions: Cities can pioneer new solutions that directly contribute to reducing emissions.

Urban areas significantly contribute to global climate change mitigation, with over half the world's population living in cities. Cities account for two-thirds of global energy consumption and over 70% of greenhouse gas emissions. To achieve carbon neutrality, city-level inventories and voluntary frameworks are used, with carbon footprint calculations being the main tool. However, ambitious regional targets can hinder progress. The carbon handprint framework provides a systematic approach to quantify and communicate the positive environmental impacts of actions implemented by cities and regions. This approach focuses on improving the performance of other actors and reducing their carbon footprint according to Laura Lakanen et al.,2022 [3].

Cities can influence private and public actors, promoting sustainability and mitigating life-cycle GHG emissions. L. Lakanen et. al [3] presents a novel approach to recognize and quantify innovative climate actions implemented by cities or regions, focusing on evaluating and quantifying emission reduction potential of climate actions. It uses the LCA-based carbon handprint approach, which focuses on the positive climate impacts a product or service may yield compared to a business-as-usual solution. The approach has been modified to include projects, organizations, and other environmental categories beyond climate change. The regional carbon handprint approach is based on existing ISO standards and research from LUT University and VTT in Finland. Consequently, the use purpose of the city carbon handprint framework was built upon three main points:

1. Bringing the focus onto opportunities for a city to be a beneficial actor in climate related issues.

2. Unveiling the significant potential of cities to act as solution providers for actors such as citizens and organizations both within and outside the city's boundaries.

3. Assisting a city to increase its handprint systematically so that benefits for the city can be maximized.

The methodology developed a four-stage framework for regional carbon handprint assessments, focusing on completeness, versatility, and accuracy.

A case study of Espoo, Finland, demonstrates the carbon handprint approach for cities. As the second-largest Finnish city with a population of 300,000, Espoo has set ambitious goals for reducing its GHG emissions by 28% by 2020 and 80% by 2030. The city has implemented emission-free and carbon-neutral district heating projects, increased renewable energy use, and advanced smart-home solutions in collaboration with public and private organizations.

The carbon handprint framework helps cities recognize climate leadership initiatives, communicate current actions, and develop future climate actions, maximizing their positive impact both internally and externally. The framework consists of four main stages:

Stage 1. Handprint requirements;
Stage 2. Additional LCA requirements;
Stage 3. Quantification; and
Stage 4. Communication.

This approach provides a scientific framework for assessing and developing large-scale mitigation activities in cities, extending existing climate work [3]. However, it also contains uncertainties and may restrict climate change mitigation activities, necessitating widespread recognition and implementation. A carbon handprint can enhance climate change mitigation and serve as a communication tool in cities, attracting residents, businesses, and initiatives, promoting innovation-driven sustainable development and transitioning from resource-dependent industrialization.

2.4 Carbon Handprints in Buildings

The integration of carbon handprint methodologies into building assessments represents a transformative approach to achieving sustainability goals. While traditional life-cycle assessments (LCA) focus on quantifying the environmental impacts of buildings, including greenhouse gas emissions, they often fail to capture the full scope of positive environmental contributions, such as carbon storage and reuse. This literature by L. C. Malabi Eberhardt et. al [7] review synthesizes existing research on the carbon handprint approach, its methodologies, applications in building projects, and challenges in implementation.

Carbon handprints are closely linked to mechanisms such as avoided emissions and absolute reductions in greenhouse gases through processes like carbon capture and storage. The notion of being "net positive" suggests that a building's handprint should exceed its footprint over time, aligning with broader goals of carbon neutrality [7].

Life-cycle assessment (LCA), defined by international standards such as ISO 14040, ISO 14067, and EN 15978, serves as the primary method for evaluating the environmental impacts of buildings. However, LCA is not yet standardized to fully incorporate carbon handprints. Methodological frameworks for calculating handprints include defining alternative market scenarios for eco-innovations and quantifying benefits caused to others. Challenges arise in effectively communicating shared handprints among supply chain operators.

Recent studies have proposed methodologies for assessing building-related carbon handprints. For instance:

- Lakanen et al. (2022) [3] developed a framework for assessing the carbon handprint potential of cities and regions, emphasizing energy-efficient buildings, renewable energy systems, and green infrastructure.

- Xi et al.'s method calculates carbonation rates in cement-based products, highlighting the role of concrete rubble in long-term carbon sequestration.

Integrating carbon handprint assessments offers significant potential for enhancing sustainability in building projects, allowing structures to simultaneously reduce their footprints and amplify positive climate contributions through strategies like renewable energy implementation and material reuse. Overcoming existing challenges through refined methodologies and standardized frameworks will be crucial for scaling these practices and embedding them within sustainable urban planning. Ultimately, advancing carbon handprint methodologies is essential for realizing the transformative potential of buildings in achieving climate resilience and fostering a net-positive environmental impact.

3. CASE STUDY: ESPOO, FINLAND

The city of Espoo undertook a comprehensive study to explore potential contributors to its carbon handprint, aiming to identify actions that could significantly reduce

the carbon footprints of its organizations and citizens. The study focused on several key areas: fostering a climate-friendly operating environment, leveraging city-owned properties and companies to promote sustainable practices, developing innovative climate solutions through city-led projects, and creating green business ecosystems while providing low-carbon facilities. This initiative not only enabled Espoo to pinpoint impactful climate actions but also positioned the city as a leader in promoting sustainable solutions, encouraging widespread adoption to address and mitigate climate change effectively [3].

Espoo's Commitment to Sustainability:

Espoo, Finland, has set ambitious sustainability goals, aiming for carbon neutrality by 2030, with a target of reducing greenhouse gas emissions by 80% compared to 1990 levels. The city has engaged in numerous initiatives, including the Sustainable Energy and Climate Action Plan (SECAP), which outlines measures for GHG reductions across different sectors. These efforts include implementing emission-free district heating projects, increasing the use of renewable energy in city-owned buildings, and advancing smart-home solutions. The integration of carbon handprint assessments into these initiatives enables Espoo to highlight its positive climate actions and enhance its urban planning strategies.

Methodology for Assessing Carbon Handprints:

Carbon handprints are evaluated through a review of overview data across various urban projects and initiatives. VTT Technical Research Centre and LUT University's research states that comparing the positive action taken with the business-as-usual baseline scenario enables the calculation of the carbon handprint. The modelling enables the layering of the data to reveal our city's carbon handprint, detailing such local initiatives as renewable energy projects, energy-efficient buildings and transportation systems. The outcome framework created for Espoo indicates that the ongoing efforts at establishing agreed-upon guidelines for carbon handprint calculation and reporting would benefit from standardized approaches.

Identifying Carbon Handprint Contributors:

In Espoo, various contributors to the carbon handprint have been identified and categorized. These include:

- Public Infrastructure Projects: Initiatives such as the development of green spaces, energy-efficient public buildings, and sustainable transportation networks contribute significantly to the city's carbon handprint by promoting low-carbon lifestyles.
- Engagement of Private Sector: When local businesses and organizations implement sustainable practices, this magnifying factor adds to the overall carbon handprint. This includes companies offering renewable energy solutions or energy efficient technologies.
- Community engagement: Residents can also be actively involved in sustainability initiatives, like community gardens and energy conservation initiatives, which promote environmental awareness and increase the carbon handprint in the city.

Implications for Urban Planning:

The inclusion of carbon handprint assessments in urban planning in Espoo has multiple implications:

- Strategic Decision Making: Knowledge on the factors which contribute to the carbon handprint guides urban planners in selecting projects that will make the biggest positive impact for climate, ensuring effective use of resources and maximizing the positive carbon impact.
- Strengthened Communication: The carbon hand print acts as a unique vehicle of sharing that allows the city to represent its sustainability effort and entice new residents and firms that want to adopt green practices.
- Benchmarking & Accountability: Conducting carbon handprint assessments allows Espoo to create a system for comparing its progress towards sustainability goals while promoting accountability within and outside the city.

Table -2: Detailed analysis of Espoo, Finland

Stage	Description	Key Activities	Outcomes
1. Handprint Requirements	Establishing the foundational requirements for assessing the carbon handprint. This includes identifying the scope and context of the assessment.	- Define boundaries for the assessment. - Identify stakeholders and their roles. - Set objectives for the carbon handprint assessment.	- Clear framework for the assessment. - Stakeholder engagement established. - Defined goals aligned with city climate initiatives.
2. LCA Requirements	Conducting a Life Cycle Assessment (LCA) to evaluate the environment	- Collect data on emissions from city operations (e.g., transportatio	- Comprehensive understanding of emissions

	al impacts associated with city operations and initiatives. This involves a comprehensive analysis of emissions across various sectors.	n, energy use). - Analyze life cycle impacts of city projects and services. - Compare with baseline scenarios to identify potential reductions.	sources. - Identification of key areas for improvement. - Data-driven insights to support decision-making.
3. Quantification	Calculating the actual carbon handprint based on the data collected in previous stages. This quantification assesses the positive impacts of initiatives aimed at reducing emissions for other stakeholders.	- Calculate emissions reductions achieved through city initiatives. - Assess benefits provided to residents and businesses (e.g., energy efficiency programs). - Use comparative metrics to quantify handprints versus footprints.	- Quantified metrics showing positive climate impacts. - Evidence-based results to communicate successes. - Identification of high-impact initiatives for future focus.
4. Communication	Effectively communicating the results of the carbon handprint assessment to stakeholders and the public. This includes marketing and branding efforts to highlight the city's climate leadership.	- Develop communication strategies to share findings with stakeholders. - Create reports and visualizations to illustrate impacts. - Engage in public outreach to promote awareness and participation in sustainability initiatives.	- Enhanced visibility of the city's climate actions. - Increased community engagement and support for sustainability efforts. - Strengthened reputation as a leader in climate action among cities.

4. STRATEGIES TO INCORPORATE CARBON HANDPRINT ASSESSMENT INTO PLANNING

4.1 Development of Carbon Handprint Standards for Benchmarking Sustainability Initiatives in Indian Cities

Establish a comprehensive framework for the formulation of carbon handprint standards specifically tailored to the Indian context, aimed at creating benchmarks for comparative analysis among urban environments across the country. This should also include the standardization of carbon handprint calculation methods and emission factors for different activities and sectors in the Indian context. This framework should facilitate the recognition and quantification of positive sustainability initiatives undertaken by Indian municipalities, thereby enhancing their capacity to mitigate climate change impacts. Such standards would leverage established methodologies from life-cycle assessment (LCA) and other relevant scientific approaches to ensure robust and scientifically sound metrics that accurately reflect the climate benefits associated with various urban sustainability actions.

India urgently needs clear, standard rules for measuring the positive environmental impact of its cities. Right now, we're good at measuring the harm, but not so much at measuring the good. Setting these standards would make cities more open about their progress and encourage them to adopt the best sustainability practices. It would also support important national goals, like the Smart Cities Mission and the National Action Plan on Climate Change, by giving us a better picture of how cities are tackling climate change. By getting everyone involved—governments, schools, and local people—we can make sustainability efforts more effective and help India reach its climate targets.

4.2 Setting the Benchmark of Carbon Handprint to A Minimum 50% For the Urban Projects and Climate Change Solutions

To effectively analyze the greenhouse gas (GHG) reduction potential of various urban solutions, projects, or business initiatives within the Indian context, it is recommended to establish a benchmark whereby the carbon handprint must exceed 50% of the baseline carbon footprint associated with the existing business-as-usual (BAU) conditions. Specifically, this means that for any proposed project, the carbon handprint generated by the new solution must be at least 50% greater than the overall carbon footprint derived from current BAU practices. This requirement should be integrated into the decision-making and approval processes for urban development initiatives.

Implementing this benchmark aligns with scientific methodologies for assessing climate impacts and fosters accountability in urban planning. The rationale for setting a 50% threshold is supported by studies indicating that significant emissions reductions are necessary to meet India's ambitious climate targets, including a commitment to reduce emissions intensity by 45% from 2005 levels by 2030 and achieve net-zero emissions by 2070.

By ensuring that new projects demonstrate a substantial positive impact on sustainability, cities can accelerate their progress towards achieving climate resilience and adherence to national policies such as the National Action Plan on Climate Change (NAPCC).

Incorporating this benchmark will not only facilitate rapid attainment of climate change prevention targets but also encourage innovative solutions that prioritize low-carbon technologies and practices. As urbanization continues to rise in India—projected to increase by 416 million people by 2050—this approach will help manage energy demand and associated emissions effectively. Ultimately, embedding such rigorous standards into city planning frameworks will enhance the overall efficacy of sustainability initiatives and contribute positively to India's climate agenda.

4.3 Introducing Residential and Commercial Building Level Carbon Handprint Assessment to Enhance the Sustainability Within the Neighbourhood

Implementing building-level carbon handprint assessments during construction and operation is crucial for sustainable urban planning in India. Large-scale projects like Surat Diamond Bourse and IT parks should undergo rigorous assessments to communicate climate impacts and enable informed decisions among stakeholders.

The carbon handprint framework quantifies positive climate impacts from building projects, focusing on energy efficiency, renewable energy generation, and material reuse. Implementing this approach is crucial for achieving carbon neutrality goals, especially in urbanizing regions like India, as buildings contribute 39% of global greenhouse gas emissions.

Government organizations like the Ministry of Housing and Urban Affairs should incentivize projects with positive climate impacts through financial incentives, streamlined approval processes, or recognition programs. This aligns with existing literature highlighting the need for standardized methodologies to quantify environmental harms and benefits in building projects.

By integrating building-level carbon handprint assessments into urban planning processes, Indian cities can enhance transparency regarding the environmental impacts of new developments while driving innovation in sustainable construction practices.

4.4 Increasing Participation in Urban Forest Reclamation and CSS Capacity Building with The Help of Organizations

Urban forests are crucial for carbon sequestration and storage, acting as carbon sinks that absorb CO2 through photosynthesis and store it as biomass. Carbon capture and storage technologies generate positive carbon handprints, and public participation is vital for environmental regenerative projects aiming to restore and enhance urban green spaces.

For instance, Handprint Tech is an organization committed to "empowering the economy's transition from extractive to regenerative" practices. A notable project undertaken by Handprint Tech is the restoration of mangroves in Situ Bondo, Indonesia, where over 30,000 mangrove trees have been planted across a 14-hectare site in collaboration with the non-governmental organization 'Yagasu'. This initiative is particularly significant as mangrove ecosystems are known to sequester carbon at rates up to 100 times faster than terrestrial forests, capturing 5 to 10 times more carbon overall.

Research indicates that urban forests can store substantial amounts of carbon; for example, studies conducted in Indian cities have demonstrated that urban green spaces contribute significantly to carbon sequestration, with Bengaluru estimated to sequester around 141.83 million tonnes of CO2 annually. To ensure transparency and accountability in these projects, Handprint Tech employs advanced monitoring technologies, including software and mobile applications, to track on-the-ground operations. This data is reported to partnering NGOs, enhancing financial transparency and demonstrating the project's environmental impact.

By leveraging innovative technologies and community engagement, cities can effectively contribute to global climate change mitigation while promoting ecological resilience and sustainability.

4.5 Enhancing Monitoring and Reporting Mechanisms for Carbon Handprint Assessments in Urban Planning

If cities are to embrace sustainable growth, they must measure and communicate their progress. That means putting in place strong monitoring and reporting systems for carbon handprint assessments. A big part of this is creating straightforward metrics to track positive impacts such as how much carbon is captured in city parks or how much energy is saved with green buildings. Of course, we can also leverage technology to do this more easily — for

example, using sensors to measure tree growth or solar panel output in real time, so our assessments are based on the most current information.

This requires that carbon handprint assessments are integrated in urban planning, where data needs to be collected in a transparent manner to ensure continuous improvement. The jury is still very much out when it comes to the impact of different types of projects on carbon reduction, and cities ought to adopt a more multidisciplinary approach to their data collection/analysis, drawing insights from disciplines ranging from environmental science to urban planning, and anything in between; only by taking a broader view will we ultimately stand a chance of making sense of our carbon handprint and its many facets. In addition, cities need to define clear reference points, or benchmarks, of their actual emissions levels to be sure that they can evaluate the impact of new projects over time. To effectively disseminate this information, cities will need to establish standardized reporting protocols on carbon handprint data, aimed at communicating with relevant stakeholders — be it the general public or policymakers — to ensure trust and accountability, while also enabling community involvement to bolster awareness and backing for unsustainability efforts. Finally, in order to keep the evaluations accurate and informative for future planning decisions, cities are constantly updating their assessments to reflect new data, technologies and lessons learned from previous work.

Developing clear metrics, leveraging technology, engaging the community, and having a system of continuous improvement around assessment practices will further increase transparency and accountability. Finally, the cumulative effect of these actions is more climate-resilient cities. This format folds in the ideas of the previous content but refreshes the flow.

5. CONCLUSIONS

Overall, once urban planning embraces carbon handprint assessments, we can see a clear line of evolving to purposeful, all-around environmental management. Taking this path goes beyond simple reduction of negative emissions, measured by the carbon footprint, to creating positive imprints through careful and strategic initiatives. Shifting the focus to optimizing a city's carbon handprint alerts urban planners to the need for strong initiatives that both prioritize emissions and encourage the advancement of sustainable behavior in those sectors.

This exploration reveals several key insights. First, urban projects with high positive impacts on the climate — such as renewable energy installations, energy efficient infrastructure or green spaces — should all be given priority. Aligning planning across levels not only advances environmental goals, it also has significant co-benefits, such as driving economic growth through green jobs, improving public health outcomes, and making communities more resilient to the growing climate crisis. In the second place, inclusivity in stakeholder engagement comprising governmental organizations, private sector actors, local residents and lobby groups to involve them in urban development planning, thereby guaranteeing the effectiveness and viability of projects put in place. Third, as it allows to establish holistic and measurable frameworks for assessing carbon handprints — thus enabling the evaluation of success of sustainability efforts.

Through robust progress monitoring from the start, cities can refine their approach as shown by data-driven insights, enabling continuous advances in environmental outcomes and capitalising on the benefits of local actions. This ability to adjust is especially important in fast urbanizing areas of the world, such as India, where development often outpaces the ability of traditional planning approaches to keep up. These cities can more holistically identify and implement innovative solutions that mitigate emissions and create opportunities for positive environmental change by incorporating carbon handprint assessments. This ultimately creates resilient urban environments that prioritize ecological health in a way that simultaneously promotes the well-being of the community while paving the way for a more sustainable future for all.

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