Policy Research Journal
ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 4, Issue 3, 2026

POLICY BRIEF ON PROMOTING SUSTAINABLE ASSEMBLY PRACTICES IN PAKISTAN: POLICY PATHWAYS FOR TRACTOR ENGINE TESTING AND ENERGY EFFICIENCY

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DOI: http://doi.org/10.5281/zenodo.18899458

Keywords

Article History
Received: 06 January 2026
Accepted: 19 February 2026
Published: 07 March 2026

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Abstract
The agricultural tractor has become important in the farming industry of Pakistan as it allows effective land clearing and lowers the cost of operation. However, the traditional methods of testing tractor engines applied in the assembly plants are based on long-term heavy-load dynamometer assessments that lead to excessive fuel consumption, heavy energy waste, and unnecessary greenhouse gas emission. This paper critically analyses the current methodologies of engine testing practiced by the tractor manufacturing industry in Pakistan and brings to the fore the implications of such methodologies on the environment and economy. A proposed hybrid testing framework is more advanced with the integration of simulation, to replace traditional one. The structure has focused on computer-aided engineering (CAE) instruments, IoT-based monitoring, integration of renewable energy and effective use of tried engines to produce electricity. Implementation of sustainable testing processes can cut down on the amount of waste in fuel each year, decrease the operational costs, decrease the emission of greenhouse gases, and towards Sustainable Development Goals (SDG 7, SDG 12, and SDG 13). The proposed solution also offers a viable avenue through which energy saving practices in industrial assembly can be promoted in Pakistan.

INTRODUCTION

Modern agriculture has turned into a fundamental component of mechanization worldwide (Wijayanto and Puspitojati, 2024). Tractors are the most popular type of mechanized equipment in Pakistan, which helps farmers to prepare seedbeds in time, manage the irrigation process, implement intercropping processes, and deal with the post-harvest operations (Memon et al., 2024). The main factor that determines efficient performance of tractor is the reliability and fuel efficiency of their diesel engines (Smith, 2012). The Pakistani market is controlled by five large tractor brands, including Millat Tractors

Ltd., Al Ghazi Tractors Ltd., Belarus Tractors, Euro Ford Tractors, and Bull Power Tractors.

Engine testing is a necessary part of tractor production, where every unit of production must comply with the requirements of quality and performance prior to delivery to farmers (Lancas et al., 2020). But the available testing methodologies in Pakistan rely completely on the physical heavy-load endurance tests. In these procedures, engines will be constantly operated in dynamometers or generators to be validated and will not produce any productive industrial output (Mahmood et al., 2025). With the world going green with green house gasses and the focus on the concept of sustainable manufacturing, it is time of the day to substitute such energy- consuming assembly processes with new, energy- efficient and in a way sustainable to the environment.

2. Existing Challenge

The tractor industry in Pakistan has been growing significantly over the past decade to support the domestic food production (T ur Rehman et al., 2016). Although this was happening, there have been no innovations in industrial assembly procedures, particularly tractor engine performance testing (Raza, et al., 2018). In a recent industrial visit conducted to Millat Tractors (Pvt.) Limited, Lahore, scholars of the University of Sargodha noticed that the engine testing of heavy-load is regularly employed as the main assessment procedure.

All tractor engines are also subjected to a test period of about 40 minutes to examine the power production, torque consistency, and mechanical dependability (Tang et al., 2025). Given the high production of tractors per year, this mode of operation causes tremendous burning of diesel fuel and electricity. This is an unproductive waste of energy and a significant environmental issue because of the emission of exhaust gases, such as CO_2, NOx, and particulate matter (Lovarelli et al., 2018).

These inefficiencies are in direct conflict to:

- Goal 7 - Affordable and Clean Energy.
- Goal 12 - Responsible Consumption and Production.
- SDG 13 - Climate Action

Thus, there is an urgent necessity to implement the cost-effective, digital, and environment-friendly testing approaches that provide the quality assurance and minimize the energy waste.

3. Materials and Methods

3.1 Assessment Framework

The research was based on an observational and analytical method:

- Check of engine testing time, fuel usage and power generation capability.
- National statistics of tractor production: industrial data analysis.
- The consultation will be made with agricultural engineers, assembly technicians, and environmental scientists.
- Review of literature on the best practices of engines testing and energy efficiency around the world.

3.2 Data Sources

The production of tractors was obtained in terms of Pakistan Economic Survey and reports of industries. Estimates of fuel consumption were determined through average engine running loads that were used in the tests.

4. Proposed Framework for Advanced Engine Testing Method

A systematic replacement framework is suggested to cope with existing challenges.

Step 1: Evaluate the Current Testing practices.

- Establish a baseline of energy use of traditional testing.
- Measure fuel consumption, electrical power consumption and emissions.
- Find technical bottlenecks.

Step 2: Define Objectives

- Cutting of operational expenses.
- Reducing reliance on fossil fuel.
- Reduction of environmental hazards.
- Reliability in the testing.

Step 3: Workout Advanced Testing Parameters.

The evaluation of the engine should be based on:

- Power Output (HP)
- Torque Stability

- RPM Fluctuations
- Fuel Efficiency
- Emission (CO_2, NOx, PM) Monitoring.

Step 4: Implement Simulation-Based Testing.

- Virtual load simulations with the use of CAE modeling.
- Digital diagnostics: IoT sensors.
- Substitute physical tests that are repeated with algorithm tests.

Step 5: Develop Hybrid Testing.

- First screening of the engine on simulations.
- Last validation using short physical tests.
- Progressive elimination of endurance heavy-load testing.

Step 6: Implement Renewable Energy.

- Power testing units using solar panels.
- Stable storage to allow constant supply.

Step 7: Certify and Standardize.

- Prepare country sustainable testing guidelines.
- Issue environmental-quality certifications.

Step 8: Monitor and Optimize

- On-going performance analytics.
- Periodical review of improvements.

5. Anticipated Benefits

5.1 Productive Energy Recovery

As per GoP (2023-24), approximately 46,272 tractors were manufactured in Pakistan. Every engine was put through 40-minute tests, and as a result, the following were gained:

- Averages Testing time per year: 30,848 hours/year.
- It is estimated that the fuel consumption is 154,240 liters/year.

It was experimentally indicated that all the tested tractor engines, when connected with generators, have on average 50-52 kVA electrical power generation. Nearly productive use of post-testing engine running can thus produce:

- 1,542,400 kVA of electricity annually

When this energy is tied to the manufacturing plant grid it can assist:

- Offset testing energy costs.
- Promote in-house power supply.
- Eliminate energy burden on the country.

5.2 Environmental and Economic Gains

- Reduce greenhouse gas emissions.
- Reduced fuel waste.
- Better adherence to the international requirements.
- Enhanced equipment life.
- Encouragement of clean energy trends.

6. Policy Recommendations

1. Government Support

- Modernize testing infrastructure with a subsidy.
- Require sustainable testing procedures.

2. Industry Collaboration

- Collaborations between universities and manufacturers.
- Contact with technology transfer offices.

3. Awareness and Training

- Train engineers CAE, IoT-based diagnostics.
- Train farmers on low energy tractors.

4. Incentives

- Tax subsidies to the compliant industries.
- Farmers discounted eco-labels.

5. Monitoring

- Energy saving independent audits.

7. Discussion

In the world, industries are abandoning conventional heavy mechanical testing in favor of intelligent digital diagnostics. Peng et al. (2023) emphasized that the hybrid testing performed with the help of simulation consumes much less resource. Likewise, the implementation of renewable energy in the process of industrial is a time-tested approach to reduce the levelized testing cost (ADB, 2023).

The fact that wasteful testing hours can be transformed into useful generation of electricity promotes the principles of the circular economy (World Bank, 2018). This can be advantageous to Pakistan through embracing such innovative practices of assembly that will make it be sustainable both in agriculture and manufacturing business.

8. Conclusion

Agricultural productivity in Pakistan highly depends on tractor engines, which have a conventional assessment in assembly plants, leading to massive energy wastage and environmental emission. The suggested advanced engine test system offers a pragmatic perspective towards ensuring increased energy efficiency, decreased fuel wastage, and environmentally friendly assembly activities. Implementation of CAE simulations, hybrid validation, and renewable energy-based testing would be beneficial to both manufacturers and farmers, as well as would help the Pakistani state to meet the goals of the UN Sustainable Development.

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