Development and Demonstration of a Smart Piezoelectric System for Port Gates
In order to limit global warming to 1.5 degrees Celsius by the turn of the century, the world needs to achieve net-zero carbon dioxide emission by 2050...

- Nations around the world are adopting eco-friendly energy policies.
- Ports across the globe are setting ESG targets for the reduction of GHG emissions, including the introduction of renewable energy sources.
- South Korea has updated its NDC target to reduce its GHG emissions by 40% of what they were in 2018 by 2030.
Electricity consumption is increasing with the pursuit of low carbon emissions and eco-friendly smart ports. While the distribution of renewable energy is increasing, constraints due to space, weather, and other factors, means that there are limitations when it comes to securing renewable energy source.

Utilising its characteristics as a port, Busan Port will overcome these limitations, using **piezoelectric energy generated vibration and pressure** of cargo trucks during passage.

### Characteristics of piezoelectricity vs. renewable energy

<table>
<thead>
<tr>
<th></th>
<th>Wind</th>
<th>Solar</th>
<th>Geothermal</th>
<th>Hydro</th>
<th>Coal-fired</th>
<th>Piezo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation cost per 1kWh (cent)</td>
<td>3-10</td>
<td>10-20</td>
<td>2-10</td>
<td>2-10</td>
<td>8-10</td>
<td>3-10*</td>
</tr>
<tr>
<td>Payback period (year)**</td>
<td>12-30</td>
<td>20-30</td>
<td>10-20</td>
<td>12-15</td>
<td>15-20</td>
<td>6-12*</td>
</tr>
<tr>
<td>Sustainability</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cleanness</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Maturity of technology</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Ease of installation/modify</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Feasibility of installation in urban areas</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

[Basis for calculation : * traffic-dependent, ** Assuming 10 cent in revenue per kWh] / Source : Israel

### Economy of piezoelectricity vs. solar

<table>
<thead>
<tr>
<th>Category</th>
<th>Solar power generation</th>
<th>Piezoelectric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation per year</td>
<td>Approx. 45MWh</td>
<td>Approx. 45MWh</td>
</tr>
<tr>
<td>Installation cost</td>
<td>KRW 87 mil. on average</td>
<td>Approx. KRW 82 mil.</td>
</tr>
<tr>
<td>Area required</td>
<td>Approx. 50㎡</td>
<td>Approx. 12㎡</td>
</tr>
<tr>
<td>Payback period</td>
<td>Approx. 8 years</td>
<td>Approx. 7.5 years</td>
</tr>
</tbody>
</table>

---

**Why do we need this initiative?**
How are we able to harvest piezoelectric energy at ports?

By addressing the limitations of piezoelectric energy on public roads.

01 Uniform weight
   of loaded / empty trucks

02 Regular pace
   Speed is limited during gate entry/exit

03 Identical path
   Gate passage is mandatory for all trucks

Project Overview

The development of technology which converts the pressure and vibration generated by container trucks entering and leaving the port terminal gates into electricity for storage and use.

Project period

November 1, 2021 ~ October 31, 2023 (24 months)
Conceptual overview of piezoelectric system

Piezoelectric module

Polyurethane

Concrete

Rubble filling

Concrete

Rubble filling

piezoelectric energy controlling board

ESS

GATE

2 M

25 cm
Project Progress

- Jan. 12, 2022: Technology development launch report and collection of stakeholder input
- Mar. 4, 2022: Field investigation into terminal gates at Pier 1 of Busan New Port (PNIT)
- Apr. 2022: Completion of development of piezoelectric modules and IoT sensor modules
- Aug. 2022 ~ Mar. 2023: Selection of Uam Pier as a test-bed, and identification of issues via field tests
- Aug. 2022: Durability testing of piezoelectric modules (temperature & humidity, dustproofing), and receipt public certification
- Sep. 2022: Completion of piezoelectric system installation manual
- Sep. 29, 2022: Application of four patents
- Dec. 28, 2022: Pre-inspection of piezoelectric system demonstrative review (PNIT)
- Feb. 7, 2023: Testing of field/remote monitoring system communication

Piezoelectric modules and casing

- Piezoelectric module case
- Upper part of the module
- Lower part of the module
- Inside of the module

IoT sensor modules

- IoT sensor module
- IoT sensor module installed

The IoT sensor module, which measures changes in vibration, temperature, and humidity, consumes only 0.53W (24V × 0.0224A).
**Milestones**

- Pre-testing of piezoelectric module
  - Maritime industry cluster used as a testing site
  - Issues resolved through integration testing for modules
  - Expected power generation estimated through mock testing

**In-field pre-testing results**

**Testing subject**
Two piezoelectric modules and 64 piezoelectric devices

**Piezoelectric module output**
Condenser (2,200uF, 50V)

**Testing conditions**
Repetition of truck operation five times at the speed of between 5~30km per hour

<table>
<thead>
<tr>
<th>Speed [Km/h]</th>
<th>No. of operations</th>
<th>Piezoelectric device output voltage [V]</th>
<th>Output energy of two piezoelectric modules [J], [Ws]</th>
<th>Output energy of one piezoelectric harvesting set [J], [Ws]</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>5</td>
<td>36</td>
<td>1.4256</td>
<td>5.7024</td>
</tr>
</tbody>
</table>

[View of maritime industry cluster site]
Demonstrative testing underway, following installation at Pier 1 of the New Port

Installation will commence at all piers of Busan New Port following the results of the tests at Pier 1 of the New Port and enhancement/improvement of piezoelectric device.
Anticipated benefits from the installation of a piezoelectric system at Busan New Port

Economic effect

Generation of 2,115MW in electric energy per year to power 705 households for one full year

* [Expected power generation] Generation of 45MW per lane per year × 47 lanes
* [Energy available for use] 2,115MW / (monthly average electricity consumption per household in Busan as of 2022 (250kwh) × 12 months)

Environmental benefits

Approx. 936.522 ton reduction in CO₂-eq
Equal to planting 149,428 pine trees

* [CO₂ emissions reduction calculation formula]
  19.926ton CO₂ eq of expected CO₂ emissions reduction per lane × 47 lanes
  [KCEN carbon footprint calculator]
Busan Port: leading the way in energy self-sufficiency with piezoelectricity!