KISR
معهد الكويت للأبحاث العلمية
KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH

KISR Inventions

2019 - 2020

Table of Contents

Introduction

The booklet is prepared by the Commercializtion Division. It represents KISR'S patents for the years (2019 - 2020). This booklet includes a summary of each patent with all necessary detailed applications, market trends, and it's benefits which are reflecting the various accomplishments at the following centers:

- Enviroment and Life Sciences Research Center (ELSRC).
- Energy and Building Research Center (EBRC).
- Petroleum Research Center (PRC).
- Water Research Center (WRC).

Desalination System with Mineral Recovery

Inventors: Dr. Bhadarachari Garudachari | Dr. Mansour Ahmed | Dr.Rajesh Kumar Alambi | Mr. Jibu P Thomas

Patent Number: US10280095 B1

Year: 2019 - **Center:** WRC

Description

Seawater desalination process occurs when natural ionic contaminants are removed completely to create suitable freshwater. The process of the removal of undesired levels of natural ionic, high-concentration solution of salts and other minerals (known as brine), which are left to be discharged as waste.

With increasing levels of demand for fresh water, desalination plants and production levels have increased in the past three decades, and so were the levels of brine disposal. High concentrated brine levels disposed within water (sea, ponds, underground, wells, etc.) or in land tend to contribute negatively to the environment.

KISR has developed a zero-liquid discharge (ZLD) desalination system with mineral recovery process using spray drying technique

that treats brine solution and allows recovery of mineral salts. It is a two-stage desalination process, with feed obtained from the seawater directly, from reverse osmosis (RO) brine, or multistage flash (MSF) brine, or nano-filtration (NF) reject.

The first stage involves spray drying of feed water to produce initial purified water and concentrated brine. The concentrated brine is then fed to the second stage, which also uses a spray drying process to produce a secondary purified water and recovered mineral salts. The introduction of heat exchange (hot/cool air) with the spray dry can be tailored and adopted to extract specific minerals, such as magnesium.

The mineral recovery capacity of different inorganic components relies on the changes of temperature and pH levels within the chamber to target desired components, without increasing the cost of energy usage or fouling the membrane filter.

Applications

A ZLD water desalination system with mineral recovery application can be used in different industries that require freshwater in their production operations and industries that tend to produce brine. Since this is a ZLD technology, this system is ideal for regions with active ZLD policies.

Benefits of the Invention

- Zero-liquid discharge desalination system is an environment-friendly approach to desalination.
- Selective recovery of valuable minerals like potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), boron (B), and lithium (Li).
- Effective approach to the utilization of limited natural resources and reduction of waste.

Market Trends

The boom in the desalination industry is expected to grow by 5.7% per year by 2030 due to continuously growing demand for freshwater, and continuous improvements in the technologies' abilities of production. Although the improvement in the desalination technologies allows for higher recovery ratio of freshwater, brine discharge into the environment (mainly the sea) remains a major environmental issue. Research indicates that the global brine production accounts for 141.5 million m^3/day, in which the Middle East & North Africa (MENA) generates 99.4 million m^3/day (70.3% of the overall brine production).

With the rising demand for more environmentally friendly desalination systems and variable minerals, the demand for ZLD technologies is expected to grow significantly by 2030. It is forecasted that by 2025, the global ZLD system market is going to grow from $6 billion to over $9 billion. Note that the compound annual growth rate (CAGR) is expected to reach over 5.5% by 2025 (Figure 1).

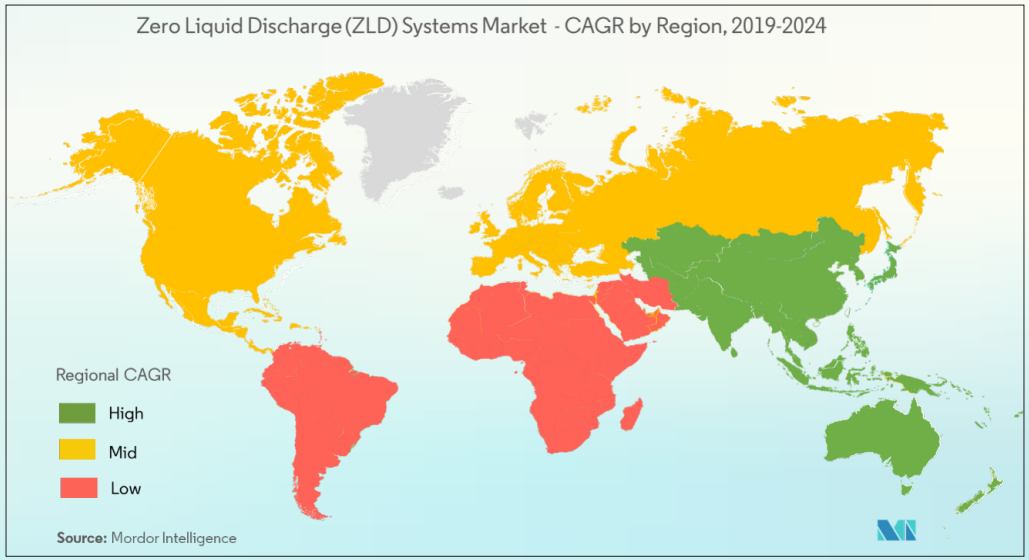


Figure 1. (Markets and markets, 2018)

Far East Asia = 41%

Australia & New Zealand = 23%

Europe = 16%

Russia = 7.2%

North America = 11%

South America = 2.7%

MENA = 0.1%

Africa = Unknown

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
    - Technology leader.
    - Environmental advocate.
    - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
    - Possibility of exporting technology to regional partners.
    - Expansion of facility at less cost.
    - Beneficiary of knowledge/technology transfer.

Pressure-Reduced Saline Water Treatment System

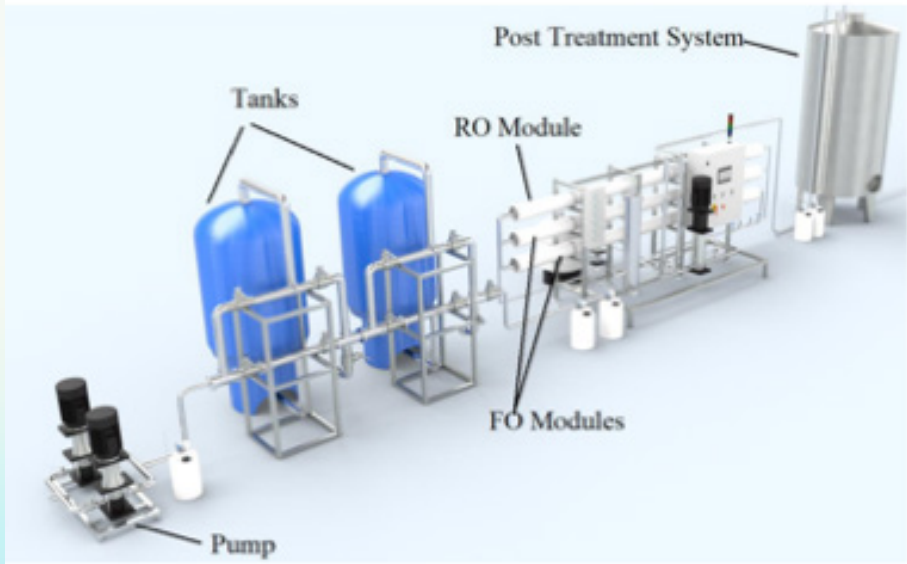
Inventors: Dr. Mansour Ahmed | Dr. Rajesh Kumar Alambi | Dr. Bhadarachari Garudachari | Dr. Yousef Al-Wazzan | Mr. Jibu P Thomas

Patent Number: US 10308524 B1

Year: 2019 - **Center:** WRC

Description

Pressure-reduced saline water treatment system is a single-phase hybrid membrane system consisting of reverse osmosis (RO) and forward osmosis (FO) technologies having unique tubing connections. The system's performance relies on the osmotic pressure gradient by taking an intake feed from the FO desalination unit, and keeping it in fluid communication with the RO unit, and vice versa. The RO system produces freshwater and brine water, where the brine (reject output) is fed back into the FO module of the hybrid system. Unlike the previous disclosures, the FO-RO single phase process has potential to re-purify the reject output of freshwater. Thus, the brine discharged by the hybrid system is low compared to the other desalination systems.



RO technologies' efficiency depends on the

pressure, flow rate, quality of the initial intake, etc. RO is a conventional desalination system, mainly used for removing salt and other solvent molecules within the feed water under high pressure. The current hybrid system is built on RO-FO integration that reduces the operation pressure to 30 bar or less, resulting in low energy requirement. The low energy requirement makes the system suitable for integration with renewable energy solutions.

The current prototype has been tested on a small scale. Future development plans includes a medium-scale proof of concept (POC) covering the technical and economic feasibility of the invention. Furthermore, research on high-pressure desalination systems with mineral recovery for zero liquid discharge applications is currently being conducted.

Applications

A water treatment system, desalination system, which can treat different water sources, including seawater, underground water, and different high saline water intakes.

Benefits of the Invention

- Energy-efficient system with ability to be integrated with renewable energy or traditional energy sources.
- Cost-effective system with a more competitive water recovery than the RO stand- alone process.
- Low brine discharge.
- More environmentally friendly.
- Market applications in regions with active low brine discharge policies or renewable energy consumption policies.

Market Trends

During the past decade, the global demand for freshwater has been met by desalination of seawater by a rate of 1%. With scarcity of freshwater, and growing demand for freshwater, demand for desalinated seawater is expected to grow by 1.5% by the year 2030. Desalination capacity is forecasted to grow by 5.7% per year by 2030, in which it is expected that the installed capacity will double in the next 11 years to be able to produce (Figure 1 and 2).

Development in lower cost desalination technologies has also contributed to the increase in demand for desalinated seawater. The global market for desalination technologies has been projected to reach US$36.8 billion by 2024, which is an estimated compound annual growth rate of 7.8% (CAGR) from 2018 to 2025. The increase in demand for desalination technology depends on the type of water, desired output, and the type of technology.

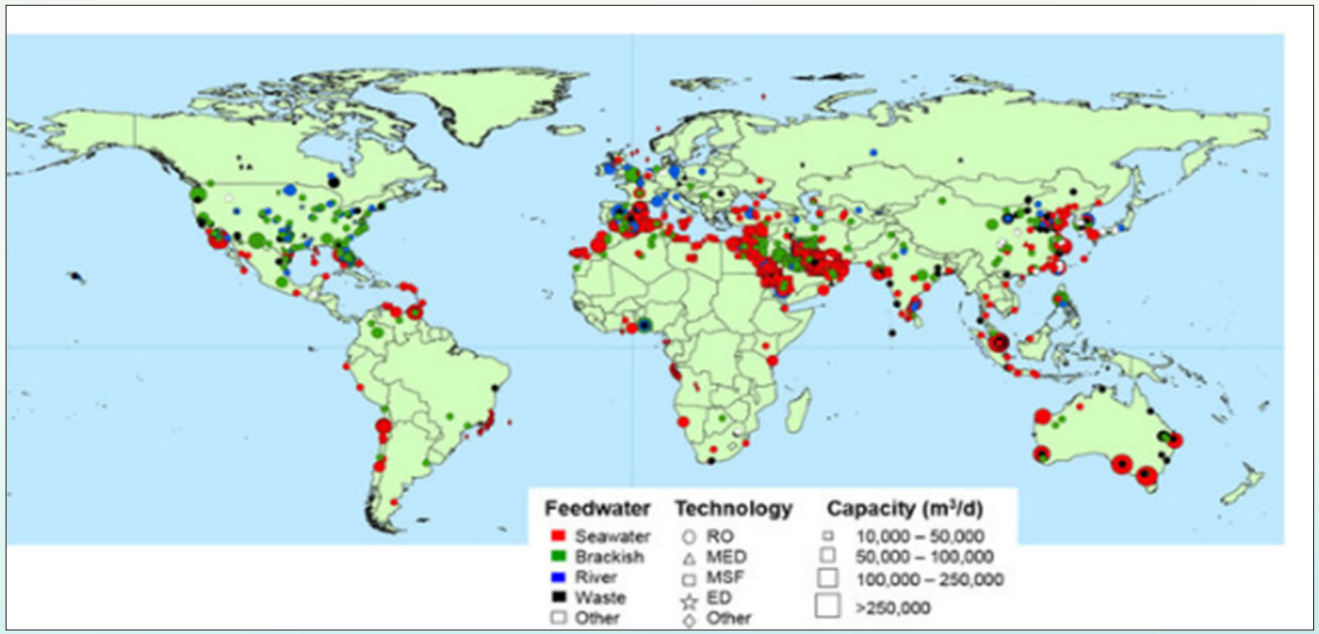


Figure 1. Global distribution of large desalination plants by capacity, feed water type, and desalination technology (Vladimir Smakhtin)

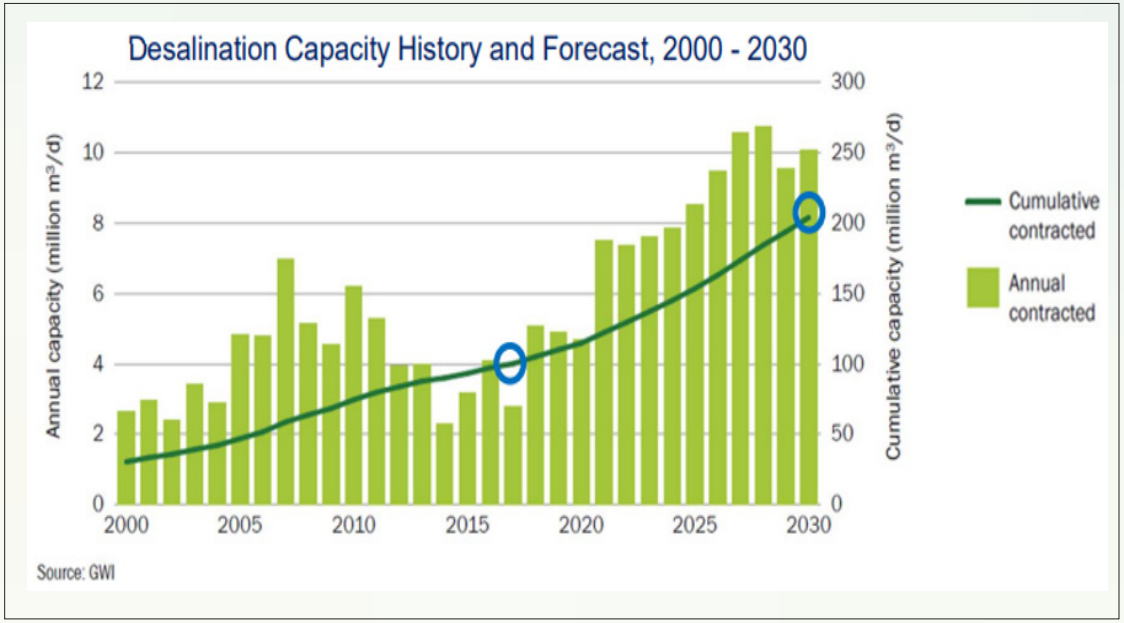


Figure 2. Desalination Capacity History & Forecast (2000–2030)

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
  - Technology leader.
  - Environmental advocate.
  - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
  - Possibility of exporting technology to regional partners.
  - Expansion of facility at less cost.
  - Beneficiary of knowledge/technology transfer.

Method for Doping Magnesium with Nickel by Cold Spray Technique

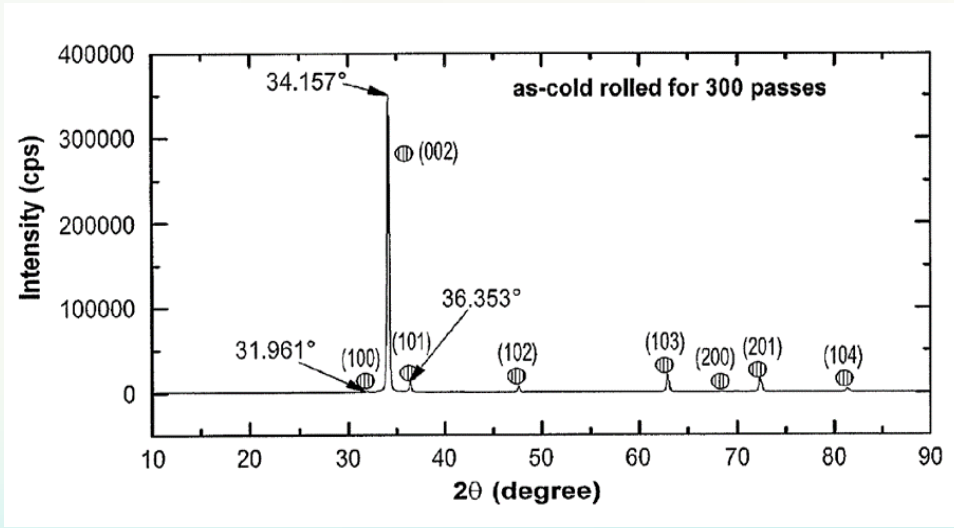
Inventors: Prof. Dr. M Sherif El-Eskandarany | Eng.Fahad T. AL-Ajmi Eng. Mohammad Banyan

Patent Number: US 10443132 B1

Year: 2019 - **Center:** EBRC

Description

There is a rapid growth in energy consumption every year; whereas the primary energy sources are limited, which result in the requirement of alternate energy sources. This invention aligns with the hydrogen-storage research trends to provide an environment-friendly solution, which corresponds to the current requirements. Furthermore, this invention relates to enhancing magnesium's storage capacity for using hydrogen in fuel cells and alternate energy sources. Moreover, this invention is a method for doping Mg with Ni, which includes cold rolling technique to produce thin Mg-nanostructured strips starting from commercial Mg rods. A cold spray powder technology was developed for coating the cold rolled Mg strips with Ni powders at nearly room temperature. This method is less expensive than the current ball milling methods used to produce Mg-based materials for hydrogen storage. The resulting Ni-doped Mg material enables the absorption of hydrogen at lower temperatures and pressures.



Note: This patent has the same applications, market trend, and benefits as the Nanocomposite System for solid Hydrogen Storage in pages 14 - 15

Patent Number US 10364148 B1

Nanocomposite System for Solid Hydrogen Storage

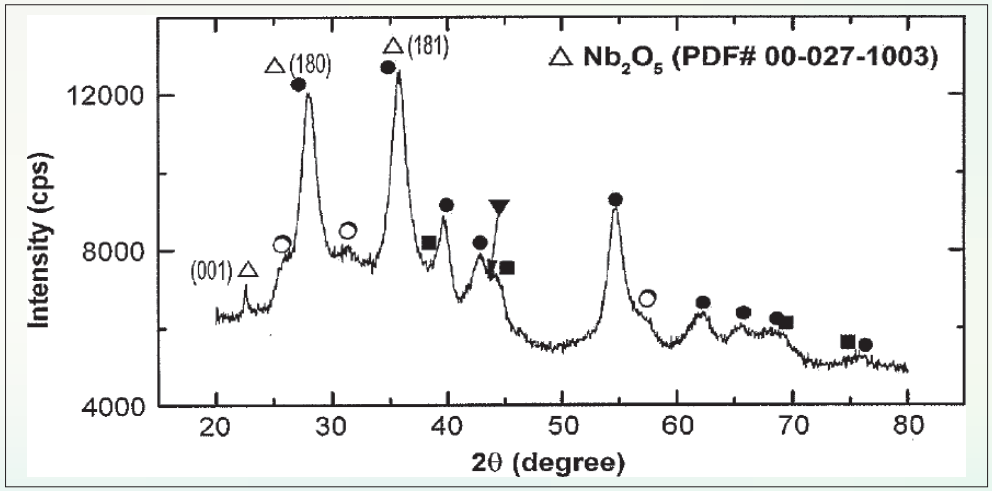
Inventors: Prof. Dr. M Sherif El-Eskandarany | Eng.Fahad T. AL-Ajmi Eng. Mohammad Banyan

Patent Number: US 10364148 B1

Year: 2019 - **Center:** EBRC

Description

The requirement of alternate energy sources is growing throughout the years. This requirement is supported by the need to reduce global warming, greenhouse emissions, and environment degradation globally. In addition, the available energy sources are not enough to meet the current energy demand. This invention contributes to the hydrogen-storage research trends by providing an environment-friendly solution. Furthermore, this invention relates to a composite of MgH_2 powder with $ZrNi_5$ powder and a combination of Nb_2O_5, TiC, and VC, which form a nanocomposite system for hydrogen storage. The nanocomposite system is formed by combining the MgH_2 powder with the $ZrNi_5$, Nb_2O_5, TiC, and VC, forming a mixture and performing reactive ball milling on the mixture, preferably for a period of 50 hours.



Applications

Fuel cell applications in automobiles, power plants, and automotive industry.

Benefits of the Invention

- Improves hydrogenation and dehydrogenation kinetics of MgH_2.
- Enhances the hydrogen storage capacity of magnesium.
- Less expensive than the current methods.
- Contributes to environment-friendly research solutions.

Market Trends

The total hydrogen storage market is expected to grow at a continuous annual growth rate (CAGR) of 8% to reach USD 1,011.2 million by 2026. Growth is anticipated due to governmental regulations that demand the utilization of cleaner fuels. Hydrogen storage market shows growth in material-based hydrogen storage with a CAGR of 6.5% from 2016 to 2021 and a CAGR of 7.2% from 2016 to 2026 (Table 1).

Form of storage	2014	2015	2016	2021	2026	CAGR (2016–2021)	CAGR (2016–2026)
Physical form	387.8	415.8	446.4	642.7	969.6	7.6%	8.1%
Material-based form	18.5	19.6	20.8	28.5	41.6	6.5%	7.2%
Total	**406.3**	**435.4**	**467.2**	**671.2**	**1,011.2**	**7.5%**	**8.0%**

Source: Secondary Research, Expert Interviews, and Markets and Markets' Analysis

Table 1. Hydrogen Storage Market Size by Form ofStorage, 2014–2026 (USD Million)

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
  - Technology leader.
  - Environmental advocate.
  - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
  - Possibility of exporting technology to regional partners.
  - Expansion of facility at less cost.
  - Beneficiary of knowledge/technology transfer.

Pyrolysis Reactor System for the Conversion and Analysis of Organic Solid Waste

Inventor: Dr. Sultan Al-Salem

Patent Number: US 10364395 B2

Year: 2019 - **Center:** ELSRC

Description

This is a novel dual gas-liquid pyrolysis reactor system for converting organic solid waste into a range of products, including non-condensable gaseous fraction, liquids (oil), waxes, and solid charm while applying innovative analysis throughout the conversion process. Pyrolysis is a process of chemically decomposing organic materials at elevated temperatures in the absence of oxygen. The reactor system comprises a fixed bed cylindrical reactor that works on the principle of pyrolysis, which can be adapted for hydrogenation and gasification reactions. The reactor's bed converts organic solid waste into a solid product and a gas-liquid product mixture through pyrolysis. The reactor also includes a three-zone furnace wherein each zone can provide a temperature of up to 850 °C with a flexible heating ramp for a better heat distribution along the reactor's body. The final products are collected through a collection unit, which is in direct communication with the reactor. The reactor's process includes a fully recoverable downstream operation where two gas/liquid separators and collection vessels can be utilized for gas, liquid, and char collection and analysis, making this process adaptable for various applications in a complete waste-to-fuel/energy process.

Applications

Waste management, energy generation, fuel from waste, and R&D in engineering sciences.

Benefits of the Invention

- Production of high conversion rates from organic solid waste including polymeric waste.
- Automatic online sampling of liquid products.
- No residue or waste product as all input is converted into products.
- Both liquid and gas products can be collected and analyzed.

Market Trends

In recent years, the global market demand for sustainable solutions of waste management and energy generation, restricted by environmental regulations, has created an increasing demand for pyrolysis reactor systems and similar technology solutions. Waste-to-Energy (WtE) technologies' market has registered an increase of 186%, with a total investment of USD 1 billion (Research and Markets, 2017). In 2012, the global market for WtE technologies was valued at USD 24 billion, with an average annual increase of 5% from 2008. This growth continued to reach a market size of USD 29 billion by 2015 at a compounded annual growth rate (CAGR) of 5.5%. The market size is expected to grow continuously from USD 33 billion in 2017 to USD 53 billion by 2025, growing at a CAGR of 6.0% from 2018 to 2025 (Research and Markets, 2017) (Figure 1 and 2).

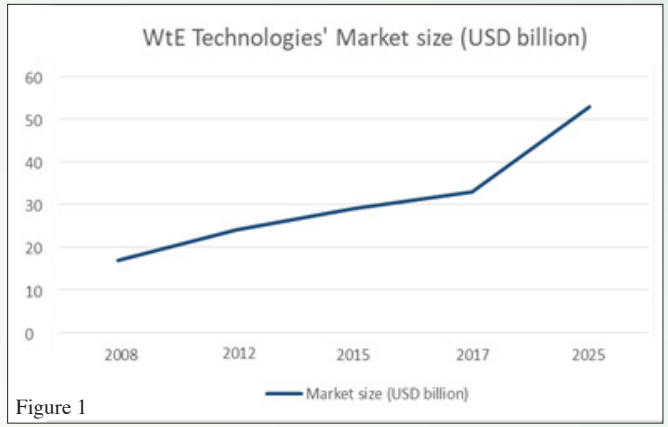


Figure 1

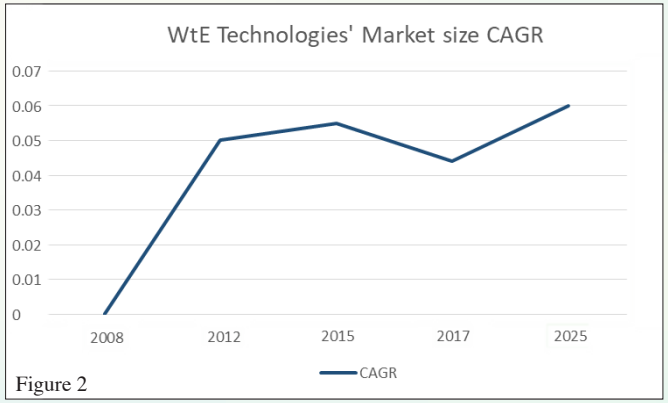


Figure 2

Figures 1 and 2. Waste-to-Energy technologies› market size change from 2008 to 2025.

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
  - Technology leader.
  - Environmental advocate.
  - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
  - Possibility of exporting technology to regional partners.
  - Expansion of facility at less cost.
  - Beneficiary of knowledge/technology transfer.

Method for Synthesizing a Thin Film Stainless Steel Coating

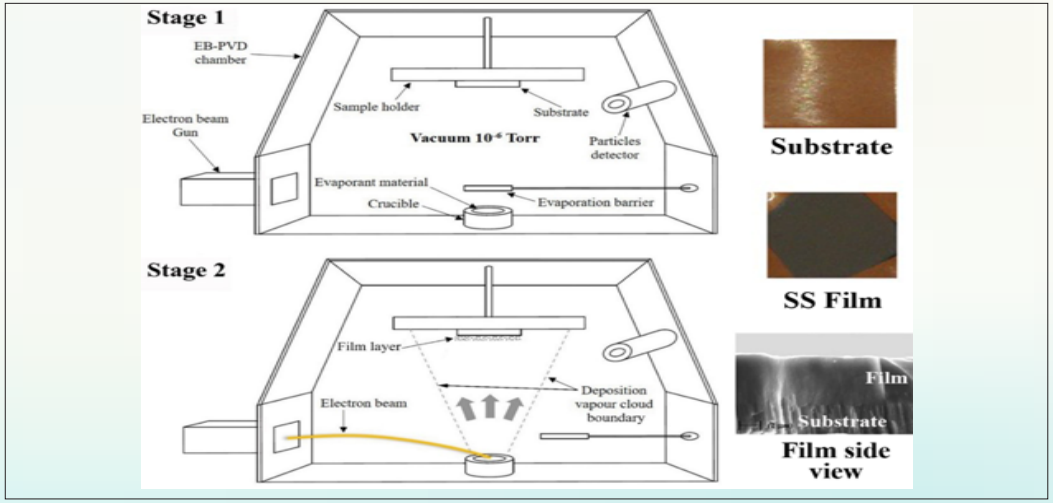
Inventors: Dr. Nasser Al-Sayegh | Dr.Maryam Adnan | Dr.Feras Al-Zubi

Patent Number: US10392690 B1

Year: 2019 - **Center:** EBRC

Description

A method for synthesizing thin film stainless steel coating using e-beam Physical Vapor Deposition (PVD) for depositing elements of stainless steel on a target surface. The method consists of thermal evaporation of a stainless steel source at a certain percentage of electron beam power and a given vacuum pressure to provide stainless steel coating layer on the target surface. The method provides a uniform stainless steel elemental distribution on the target surface. It also provides different categories or grades of stainless steel thin films from a single evaporation source. The deposited thin film shows high precision controlled thickness, uniformity, contamination free and anti-corrosive properties. On the industrial scale, this approach is considered relatively cheap compared to existing methods.



Applications

Coatings for anti-corrosion protection can be used for crude oil pipes in oil and gas, heat exchangers and boilers, automotive parts, and daily used products.

Benefits of the Invention

- Provides contamination free and anti-corrosive properties for surface protection.
- Shows high precision and controllability.
- Reduces cost on a commercial scale.
- Allows for the deposition of different grades of stainless steel thin films.

Market Trends

The result of this invention is stainless steel thin films (i.e. ≥ 1nm) of different grades (e.g. 200, 300, or other families), which contribute to many coating applications. Examples of stainless steel applications include construction, transportation, heavy industry, and consumer goods. The following (Figure 1) is the global stainless steel market by applications for the duration 2014–2025 (in Billion USD), which clearly indicates the market growth over the years.

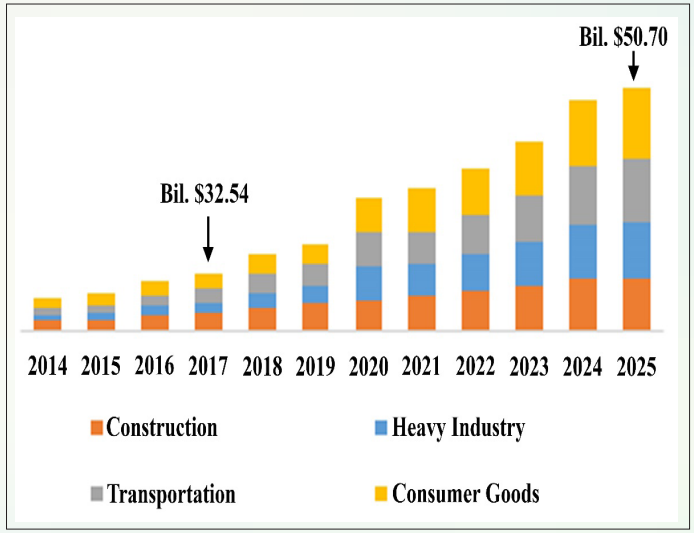


Figure 1: Global Stainless-Steel Market by Applications from 2014 to 2025 (Source: Ameri Research Inc.)

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
  - Technology leader.
  - Environmental advocate.
  - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
  - Possibility of exporting technology to regional partners.
  - Expansion of facility at less cost.
  - Beneficiary of knowledge/technology transfer.

Method for Damping Ocean Waves in a Coastal Area

Inventors: Dr. S. Neelamani & Eng.Noor Al-Anjari

Patent Number: US 10550534 B1

Year: 2020 - **Center:** ELSRC

Description

KISR developed an innovative design for damping ocean waves in coastal areas to be used as an alternative to rubble mound barriers that costs less and provides more efficient wave control. The design includes 42 different compartmentalized designs based on number combinations of walls and slots. Furthermore, this design can be applied for deep sea structures as well as costal structures.

Moreover, this design consists of vertical slotted barriers fixed by reinforced concrete placed at the seabed. The number and the width of the barriers can be customized based on area conditions. The barriers dissipate the wave energy as the waves goes through them. The dissipation rate varies according to the desirable design and application.

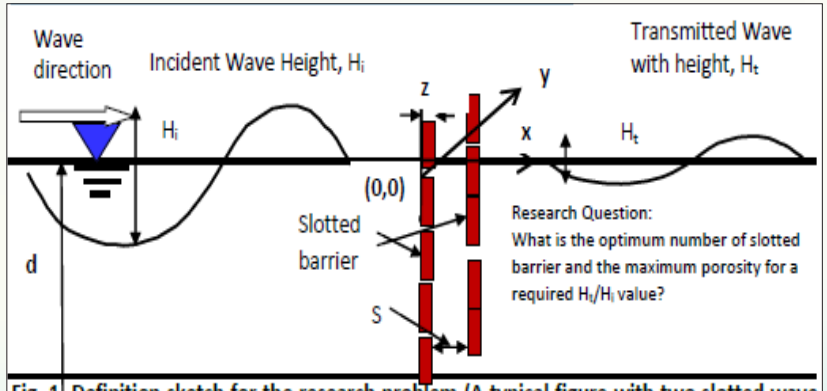


Fig. 1 Definition sketch for the research problem (A typical figure with two slotted wave barrier-another 41 configuration exists).

Applications

A water wave damping system can be used for dissipating wave energy in coastal area, including ports, seaside buildings, beaches, and aquamarine structures. This system is ideal solution to maintain good water quality and marine life with minimum cost, resources, and environmental impact.

Benefits of the Invention

- Can be applied in different structures including beaches, open sea swimming pool, ports, and others.
- Open sea construction.
- Save aqua cultural cages from damage of waves.
- Provides natural habitat for living organisms.
- Minimum effect on currents.
- Simple and efficient design that can be adapted to the location and purpose.
- Low maintenance and initial cost as compared to rubble mounts.

Market Trends

According to a market study on the Global Breakwaters Market Growth (2019–2024, 2019), over the next five years, the breakwaters' construction services market will register a 2.22% CAGR (compound annual growth rate) in terms of revenue, and the global market size will reach US$ 2299.12 million by 2024, from US$ 2014.96 million in 2018. Figure 1 shows the market size growth rate for the period 2014–2024 ($ millions) of the global breakwaters construction services.

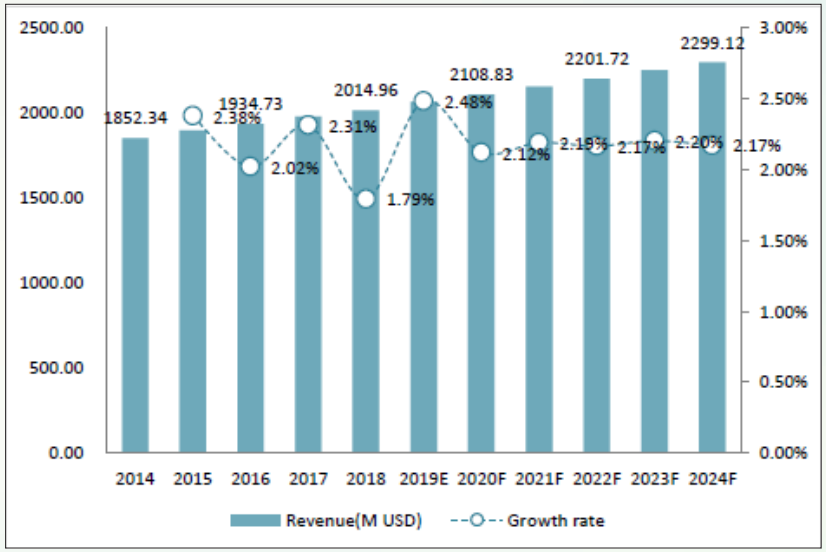


Figure 1. Global Breakwaters Construction Services Market Size Growth Rate 2014–2024 ($ millions)

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
  - Technology leader.
  - Environmental advocate.
  - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
  - Possibility of exporting technology to regional partners.
  - Expansion of facility at less cost.
  - Beneficiary of knowledge/technology transfer.

(Family Patents)
Device and Method for Measuring Effect of Soiling on Photovoltaic Device

Inventors: Dr. Feras Al-Zubi | Abdullah R. Alkandary | Abdulwahab Al-Asfour

Parent Patent Number: US 10447201 B1

Continuation in Part (CIP) Patent Number: US 10476431 B1

Continuation in Part (CIP) Patent Number: US 10594258 B1

Continuation in Part (CIP) Patent Number: US 10615745 B1

Year: 2019-2020 - **Center:** EBRC

Parent Patent Description

A device and method for measuring the effect of soiling on the performance of a photovoltaic (PV) device and, in particular, maximum power and short circuit current reduction, and/or other electrical parameters affected by soil accumulation. It utilizes a single PV device that is shifted between three stations: when (1) directly exposed to illumination; (2) placed under a cleaned glass; and (3) placed under soiled glass. A soiling ratio and soiling loss are then calculated through the measured electrical parameters in the three stations to monitor the performance of the PV device. This patent was developed further, which resulted in three continuations in part (CIP) patents, in which the original concept is modified and adjusted.

First CIP Patent Description

A device and method for measuring and evaluating the effectiveness of incorporating anti-soiling solutions and photovoltaics (PV) covers against the reference PV device cover, in which more stations were added to test different soiling solutions.

Second CIP Pending Patent Description

A method for measuring spatial soiling distribution to identify its uniformity on PV surfaces, utilizing the device claimed in the parent patent. This method differs from the original as it spatially resolves the soiling distribution in station 3 providing a single 2-dimensional soiling ratio matrix, consisting of sequential SR measurements providing more data. In addition, the method results in generating a soiling uniformity index (SUI) using the SR values obtained.

Third CIP Pending Patent Description

A method for electro-optical soiling isolation, in which a comprehensive five-step procedure is applied to optimize the optical and physical properties of the covers and setup to reduce the cover-induced errors. This method allows for measurement under higher soiling concentrations, and it reduces the three conditions mentioned in the parent patent down to two conditions only: clean and soiled. The reduction of the conditions under which the device is tested reduces errors.

Applications

Solar energy: Commercial and academic soiling studies, PV device performance measurement.

Benefits of the Invention

- Minimizes uncertainties in photovoltaic soiling measurement.
- Optimizes cleaning frequency and pre-construction PV plant designs to reduce maintenance and operation costs.
- Builds energy prediction models.
- Provides practical tests of PV glass and coatings.

Market Trends

The global solar power market size was estimated to be 680.22GW in 2019 and is projected to reach 4766.82GW by 2026, exhibiting a Compound Annual Growth Rate of 30.7% (Fortune Business Insight). Due to the increase in R&D and market trends toward environment-friendly technology solutions, PVs and PV-related technologies are expected to have a growing market potential that is directly related to market growth for PV soiling measurement devices. As more and more PV devices are utilized, more efficient technical solutions are needed. This puts KISR's PV technology innovation in a desirable position that is aligned with the market trends. Figure 1 represents the world annual solar PV market scenarios 2018-2022 including low, medium, and high scenarios, all of which indicate growth of the solar PV market from 2018 to 2022.

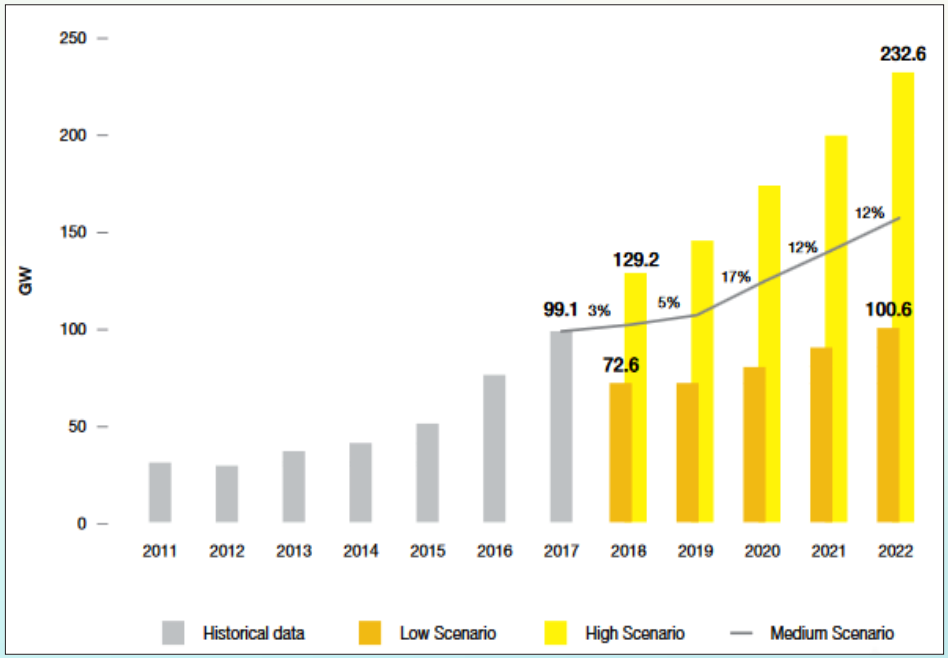


Figure 1: World Annual Solar PV Market Scenarios 2018-2022 (Source: Solar Power Europe/Global Market Outlook for Solar Power 2018-2022)

Benefits of Partnership with KISR

- Competitive advantage in the market.
- First rights to technology.
- Enhanced reputation on national and regional level.
    - Technology leader.
    - Environmental advocate.
    - First to champion Kuwait-led innovative technology.
- Improved and more consistent quality.
- Access to future collaborations.
    - Possibility of exporting technology to regional partners.
    - Expansion of facility at less cost.
    - Beneficiary of knowledge/technology transfer.