The intensification of industrial salt production using the salt production house concept

F Y Prabawa*, R Bramawanto†

1 Marine Research Center, The Republic Indonesian Ministry of Marine Affairs & Fisheries, Jakarta, Indonesia

* jeromeviril2019@gmail.com

Abstract. The current national salt demand in 2021 is 4.6 million tons, 84% of it: for manufacturing purposes. The volume of imported salt reaches 50.29 percent of the national salt availability. This high import is caused by lack of the industrial salt. In the 2020-2024 RPJMN, the total national salt production target in 2021 is 3 million tons, not enough, due to the natural conditions of high rainfall. KKP and Kemenkomarves are targeting to increase production through intensification and extensification of salt pond land, which is planned to be carried out in Flores and Sumbawa. However, according to our rough calculation, to meet the amount of national salt need, if the choice is the extensification: this will need 20 thousand hectares of newponds. This is hard option to proceed, because there are obstacles: limited land, not all types of land can be used for salt farming, high costs, long land clearing time, and dependence on weather. Plus, the negative impact on the environment from the land conversion. What is the alternative solution? This study aims to figure the solution for improving the industrial salt production. Methods are the analytical descriptive study, collecting data with reference studies, then compiling data for the formulation of the model. Study results: the suitable option to do is the intensification of the salt production. More efforts are needed on the intensification, by increasing the quantity of salt production, parallel with improving its quality, and could continuously producing salt in a full year. To fulfill this, this study recommends a technological engineering approach, by using a combination of the Japanese Method with the closed system called: the Salt Production House (SPH). The SPH is green and sustainable concept, because it consumes renewable energy, effective and require a small area. This method requires no new land clearing since it could be constructed on the existing salt ponds.

1. Introduction
Salt is a strategic commodity whose use is very broad, ranging from the petrochemical, pulp and paper, pharmaceutical and cosmetic industries, oil drilling, various foods, to household consumption. According to the Ministry of Industry, the current national salt demand in 2021 is 4.6 million tons, 84% of which is for manufacturing purposes or 3.74 million tons [1]. Based on the 2020 salt balance, the volume of imported salt contributes up to 50.29 percent of the national salt availability [2]. The high import of salt is because local salt has not been able to meet the requirements of the manufacturing sector. By the end of 2020, salt from domestic farmers is predicted to reach 2.89 million tons, while local salt stocks from 2019 will reach 2.11 million tons [3]. To meet this year's needs, the relevant Ministry, namely the Ministry of Industry, has coordinated with the KKP/Ministry of Maritime Affairs
and Fisheries, regarding data on current local salt stocks, most of which are in eight central locations. The eight centers are Cirebon Regency, Indramayu Regency, Rembang Regency, Pati Regency, Sampang Regency, Pamekasan Regency, Sumenep Regency, and Bima Regency [4]. Based on the data from the KKP, the Ministry of Industry will oversee the absorption of local salt stocks by the salt processing industry under the coordination of the Indonesian Salt User Industry Association (AIPGI), of course by paying attention to the quality of the available salt stocks, continue to optimize the absorption of local salt this year and be able to find the best solution in facilitating the process of absorption of local salt by the industry [5].

In the years 2020-2024 RPJMN, the National Plant for Long Term Development, the total national salt production target in 2021 is 3 million tons, which has not yet been met, due to unfavorable natural conditions due to high rainfall [6]. Meanwhile, national salt production from PT Garam enterprise and people’s salt is still stuck at approximately 1.3 million tons based on January 15, 2021 data from the KKP [7]. Kemkomarves, Coordinating Ministry for Maritime and Investment targets to increase production through various efforts such as intensification of production and also extensification of land for salt ponds, in collaboration with The Agency for The Assessment and Application of Technology BPPT, KKP, the Meteorological, Geophysical, and Climatology Agency or BMKG and various other agencies. The salt land extensification process with plans for the next several places such as Kupang Bay, Malacca, Nagekeo, Central South Timor, East Nusa Tenggara Province, and Sumbawa, West Nusa Tenggara Province [8]. In addition, KKP through the Salt Business Program (PUGAR) and SEGAR focuses on land intensification and salt processing. 7 units of Mini Washing Plants have been established with a capacity of 20 tons per day spread across Karawang, Indramayu, West Java Province, Brebes, Pati, Central Java Province, and Gresik, Pasuruan, and Sampang, East Java Province. A factory to process people’s salt into industrial salt has been built with capacity of 40,000 tons per year in Manyar, Gresik, East Java Province, and 27 units of the National Salt Warehouse have been built with a capacity of 57,000 tons [9].

The other side, BPPT focuses on technology to conduct salt refining or Salt Refinery Plant, and currently there is one finished pilot project with a capacity of 40,000 tons per year which is planned to be tested by PT Garam state’s enterprise, settled at Pamekasan Madura East Java Province in [10]. There are 7 units of Mini Washing Plant by KKP and Salt Refinery Plant by BPPT with a capacity of 40,000 tons per year and Sampang Salt Refinery Plant, East Java with a capacity of 60,000 tons per year, as well as those in Gresik with a capacity of 30,000 tons per year and has been built by PT Garam [11]. At least there is already local salt with industrial salt quality according to SNI or Indonesian National Standard. BPPT under the coordination of the Ministry of Research and Technology has launched a program to increase local salt uptake by the industrial sector, including the CAP/ Chlor Alkali Plant industry [12]. BPPT plans to build a pilot plant that implements landless salt technology or salt from rejected brine PLTU Suralaya power plan [13]. The Association of Indonesian Food and Beverage Entrepreneurs (GAPMMI) has also committed to increasing the absorption of people’s salt, in addition to continuing to use imported salt. The need for raw materials for salt in the food and beverage industry for this year will be around 743,000 tons. This figure is higher than last year’s 530,000 tons [14].

All of the information above is a description of the work of the Government from various agencies, and non-government parties, namely the business sector, in an effort to optimize local salt absorption to meetsalt needs, especially industrial salt and other specific salts. Local people's salt production is generally in the form of krosok or raw salt, and the amount is less, so that the shortage of industrial salt is imported. Some efforts to intensify and extensify land for salt ponds are carried out. Our rough calculation, to meet the amount of salt, if the expansion of the pond area is carried out, it will take up to 20 thousand hectares of new pond land. This is not easy to achieve, because: limited land, land use change, not all types of land can be used for salt ponds, expensive costs, long time, constrained dependence on weather, and the quality of traditional people's salt that does not meet the requirements.

Not to mention the tremendous impacts on the environment from the conversion of local natural ecological functions of coastal forests, sand dunes and so on into ponds where land and vegetation clearing will of course change the ecological function and causing endemic local and biota. So, how is
the alternative suitable way to improve industrial salt’s production? This study is aimed to compile the option of: extensification and the intensification in salt sector, and then figure the suitable solution for improving the industrial salt production, with less impact on the environment, low cost, imply green energy as well, and then recommend the result in a conceptual model.

2. Tools and Methods

2.1. Location Determination
The main research location District of Pademawu, Pamekasan Regency, Madura, East Java Province. geographically is located at 113° 19' - 113° 58' South Latitude, and 6° 51' 7.0'' East Longitude (Figure 1). At north part study location is bordered by the Java Sea, in the south by the Madura Strait, in the west with Sampang Regency and in the east with Sumenep Regency [15]. The area of salt ponds in Pamekasan Regency reaches 2113.35 ha consisting of people's traditional salt ponds around 913.6 ha and PT. Garam corporation’s area of 1122.4 ha [16].

![Research Location of SPH, 2021](image)

Figure 1. Study Location, Pademawu District, Pamekasan Regency, Madura, East Java Province.[Basic picture is adopted from www.wikipedia.com.]

2.2. Data Collection
This study uses a model ADDIE development model, by [17], which comprised of 5 stages: 1. Analysis, 2. Design, 3. Development, 4. Implementation, and 5. Evaluation. From 5 stages of the ADDIE, this research focused on the first and second stages, namely stages of Analysis (analysis) and Design (design). The first stage consists of two analyzes, including: 1) performance analysis, and 2) needs analysis [18]. Performance analysis is used to find out the common technology used, salt production and the problems faced by farmers Pamekasan Regency salt and the analysis needs is used to know the needs of industrial salt. The second stage is to design a conceptual model in engineering about salt production, and the recommendation to improve salt production as well salt quality, especially to produce industrial salt. The basis for this design is obtained from the results of analysis in the first stage. Here's the model chart ADDIE development (Figure 2). Data collection taken from secondary sources, by reference study:
papers, newspapers, reports, statistics, internet sources etc. Data types are: physical salt ponds area, the amount of salt production, the salt production stages, infrastructure used and technology. This research study was held simultaneously during 2018 – 2020 facilitated by APBN Pusriskel KKP.

2.3. Data processed
The obtained data was compiled and analyzed, calculated, and developed using Microsoft Words and Excels tabulation, design and simulation was drafted in illustration display as additional work.

2.4. Analysis
The analysis was performed qualitatively descriptive. Its analysis involving a comparative and synthetic work, and finally constructing a conceptual model and action plan recommendation.

![Figure 2. Model Chart ADDIE development](https://kloudlearn.medium.com/overview-of-the-addie-model-in-instructional-design-300cce7f8ea)

3. Results and Discussions
The common salt production stages are noted as [19] Seawater as the main ingredient salt production is channeled to plots/ponds evaporation pond. When seawater is evaporated then different types of salt will be formed. Sea water evaporated until reduced by 60% of the volume initially. After that it flows into the next pool until the next stage a precipitate is formed CaCO3. After 15% of the initial volume then CaSO4 precipitate is formed. The next stage is setting at seawater concentration or Baume level between 25-29°Be where the maximum NaCl content will be obtained. (Figure 3).
3.1 The Existing Technology Use in Salt Production

To meet the need for salt, with the least risk of loss, the people’s salt farmers use technology intervention, in the form of a semi closed system. Salt House is a semi closed system that implied in salt production. This method has been implemented; some units have been developed in countries with the addition of technology. In Indonesia too, traditional salt farming using semi closed system has been implied in several places in Java, such as in Rembang, Central Java and Lamongan, East Java, and at Pangkep, South Celebes, and at Madura Island at Pademawu, Pamekasan [20]. But every part of the salt house is still very simple, the building materials are bamboo, wood and plastic roof. The advantage of this semi closed is it can continue to produce salt even in the rainy season. It is called: Tunnel System [21].

Source: https://eusalt.com/about/salt-production/solar-salt/

Figure 3. Conventional salt production stages

Figure 4. Existing local traditional Tunnel System (personal documentation)
The tunnel roof here is made from plastic sheets, covering the circle shape frames, made from bamboo and woods. It is functioned to cover salt pond from rainwater, so farmers could produce salt in all time of the year. This system is semi closed, because not all of a unit is covered totally. Tunnel System is just one technological intervention to implied for keeping salt production up in all days in a year. There are many other variables having also significant positive changes to salt production influencing the dynamics of salt production including its output. First, there is the Index Kesesuaian Garam (IKG), or Salt Location Suitability Index, the aspect of location for creating salt ponds [22]. Next, meteorology aspect, then technology aspect [23]. The IKG location index is scoped on types of soil, as well the condition of sea water as the raw material for salt production. The meteorology aspects including wind, sun radiation, temperature, rainfall, humidity. This aspect is most important, since the major part of all salt production stages is the evaporation of sea water [24]. Least but not last, technology aspect; the method, technic, instrumentation, machine and facilities in salt production stages are also important that could influence the output. Besides, there are other factors related to the output achievement, such: funding, skill of workers, number of workers, land wide area, quantity and quality of sea water, etc. [25].

The other case of technology intervention in Indonesia notably people’s salt ponds is the use of geo-isolator, or geomembrane or geotextile as base of salt concentration table [Figure 5A]. This method has been implied on many local regions. Based on a note from PT Garam which introduced the use of geo-isolators in large areas, there are several advantages obtained from the application of this technology [26]. The use of geo-isolators can increase production by 40 percent, compared to conventional method. This number is obtained from the efficiency of land preparation time and harvest time. The amount of salt production has increased and the quality of salt has improved significantly. Almost all salt yields are high quality salt (K1) with the physical appearance of whiter salt [24,26]. This single type of technological intervention has 2 functions: improve the quantity and improve the quality of salt as well.

The other method is the use of prismatic closed system, as implied at Lamongan, East Java Province [27]. This method combines the use of geo-isolator and the roof [Figure 5B]. In a prism method unit, geo-isolator is used as the base of the salt pond and a transparent plastic sheet as roof in the prism form, to increase the internal temperature and to protect the salt from rainwater as well. Farmers could produce salt all year round without worrying about weather conditions [28]. So, this method of full closed method combining 2 types of technological engineering; geo-isolator uses and closed system in prism form, has 4 functions: all time in a year production, improve the quantity and the quality of salt, as well speeding up the production,

Figure 5. A) Geo-membrane use at salt ponds, B) Prism House Method in Lamongan, East Java Province [private documentation].
The other modern-day technic is called Japanese method. It is implied in 2018 at Pamekasan Regency, Madura the Salt Island, East Java Province, Padellegan Village, neighbor of this research location’s village: Bunder Village. This method could increase salt output in tripled time compared to conventional method. Normally the number of salts that yielded in a single hectare is 60 – 120 tons per season, it is mentioned that this method could yield 390 tons of salt, compared to conventional method in 120 tons hectare per season [29]. This implication of this method there is born from the collaborative work between Ministry of Researches and Technology and University of Trunojoyo, Madura Island. In stage concentration pond, commonly in conventional method the duration needed is 8 to 10 days, before continued to last stage: crystallization table. This Japanese method could shortcut that duration to just 3 – 4 days, so this is a type of speeding up technology intervention in production process. The working process of this salt technology, clean seawater is inserted and then rotated vertically, resulting sea water in a higher Baume (salt’s concentration in sea water) to be deposited into rough salt more quickly, by using the approach of exposing seawater to the air and the heat of the sun in the hope that the Baume number will be increased easily.

The summary is, this method has 2 types of technology intervention: increasing quantity of salt yield, with speeding up the production process. But the spotlight of this method is; it could increase salt yield tripled compared to conventional method. The ultimate technology for processing sea water before entering salt concentration table for salt crystallization is the key, by increasing Salt Concentration or Baume level in shorter time. In general, the next comparation is Salt Yield from the existing methods, as seen in Figure 6.

![Salt Yield](image)

**Figure 6.** Graph of Salt Yield Comparation between the existing Farming Methods

Figure 6 shows that normal salt yield from traditional or conventional people’s salt farming method [A] is around 60 ton per Hectare per season/ 3 - 4 months in dry season in a year cycle. Then, [B] PT. Garam, a state owned enterprise reached a success by increasing salt yield to 40%, or equal to total of 120 ton per hectare, by several technic, especially the use of Geo-isolator. At the other part, [C] people’s salt farmer at several regions also achieved success with the Tunnel Roof System, so they could keep produce salt in rainy season. So, the simulation of salt yield calculation is, same salt’s yield number: 60ton/HA/4 months in Dry Season x 3 = 180 ton/HA/year. [D] The Prism roofed method, using closed system, with Geo-isolator, so this method is estimated to yield 120 ton/HA x 3 = 360 ton/HA/year. [E] is Japanese Method, it is informed that its salt yield could reach triple times of conventional salt yield = 390 ton/HA/year. Next method is [F], the simulation of Japanese Method that combined with closed system: Salt House, this means = 390 ton/HA/year x 3 cycles = 1.170 ton/HA/year.
3.2 The Existing Problems
Reviewing all methods of salt farming implied in Indonesia, we could classify them into: A) traditional or conventional: outdoor, dry season farming only, simple method and technology; B) Conventional method with technology intervention: (i) outdoor, dry season farming: geo-isolator use (ii) indoor, all season’s farming: Tunnel Plastic Roofed System, prism plastic roofed system, and the Japanese Method. Table 1.

A common problem in traditional or conventional method is rainy season, farmers usually stop production during this season. Farmers usually produce salt in 3 to 4 effective months in a year, during dry season. But this obstacle could be solved with semi closed system: Tunnel System or full closed system such Prism house, so the production could proceed all days in a year. Still, these alternative methods have problems, such: the lack of sunlight radiation as an important variable in evaporation, during cloudy and rain in the rainy season. More, in rainy season, the cloudy sky and rainy weather could decrease the air temperature. Even though the production can continue during the rainy season, low temperature during rainy season also arose as an obstacle. These conditions could be overcome with technological intervention.

The Japanese method has weaknesses, that it could not be implied in rainy season, it is a base problem same as the traditional or conventional method. So, this method still experiences the same problem as those conventional method; that could produce salt only in 3 – 4 months in dry season in a year. Plus, the vertical sea water process in this method needs high consume of energy for its pumping instrumentations used. At first launching in 2018 at Pamekasan Regency, the running of Japanese method used fossil-based energy. This means this method is still inefficient in cost, and not environmentally friendly as well. Irony, it is the opposite of the SDG’s commitment in environment air quality guarding action. Besides, this Japanese Method is still same as traditional people’s salt method: rely on wider area to achieve more salt yield. This means, this method still needs 10 to 20 thousand hectares more new land to be opened as salt’s ponds. And this is not the best solution in national’s problem: lack of industrial salt’s supply, as well lack of land. Further, this method is effective and applicable or easy to imply, if it combined to closed system, weather it is Tunnel outdoor Semi Closed System, or the indoor full closed system such Prism method. So, the production could proceed all days in a year.

3.3 Projection of industrial salt production in scope national salt demand
Salt consumption contains a minimum of 94% NaCl, while salt for the diet need up to 60% of NaCl, meanwhile, salt for industrial needs NaCl concentration in salt of minimum 97% [30]. Local salt, called “Krosok” salt or raw salt commonly produced with NaCl concentration below 97%. So, to produce industrial salt, it is needed further process to upgrade the raw salt becoming industrial salt. The existing technology implied in Indonesia is using Washer processing Machine. Some private companies have been using big capacity processing plant machines, while the state has distributed 7 mini washer plants at 7 salt centralized regencies. Later, there is 1 bigger capacity of washer plant, type of processing plant that established at Manyar, Gresik Regency, East Java Province [31]. Total of local industrial salt production in year 2021 is 91.100 Tons, shown at Table 1.

| Table 1. Local industrial salt production, 2021 |
|------------------------------------------------|
| **No.** | **Industrial Salt Processing Facility** | **Location** | **Yield (Ton/Year)** |
|---------|----------------------------------------|--------------|---------------------|
| 1       | mini washer plant                       | 7            | 51,100              |
| 2       | processing plant                        | Manyar       | 40,000              |
|         | total                                   |              | 91,100              |
Table 2 displays the map of national industrial salt demand and the local capacity of production. It is shown that: column [A]: The industrial salt demand in 2021 is estimated around 3 million of Ton/MT. There’s an addition in number for reserve purpose, so the imported salt became 4.6 MT. 84% of this number are import allocations for industry [32]. In column [B]: the existing local industrial salt yield could fulfill around 2% of total national demand on industrial salt. [C] shows local raw salt’s production is totally around 1.3 MT. There’s a huge gap, [B] deficit of industrial salt >90%, which this number is fulfilled with the import. Even, there is deficit of raw salt to process to be upgraded into industrial salt as shown in [C]. To produce 3 MT of industrial salt, it is needed a greater number of raw salts as raw material. So, we assume it is around 4 MT of raw salt that is needed to transformed to industrial salts. This is the first number to focused: by increasing the quantity of raw salt reaching 4 MT. This means, the raw salt yield should be increased tripled, or around 3.9 MT per year. In Table 3, it is shown the result of calculation on total salt yield per year refer to the simulation of method use.

### Table 2. Simulation of salt production from the the existing farming methods and correlation to national salt demand

| No | A | B | C | D |
|----|---|---|---|---|
| National Demand [MT/Year] | Industrial Salt Demand 2021 | Total Industrial Salt Production 2021 [MT/Year] | Local Raw Salt Production 2021 [MT/Year] | Simulation of Targeted more local raw salt production, using innovated method 6F [MT/Year] |
| 3 + reserve = 4.6 | 0.09 (2%) | 1.3 | 3.9 |

Table 3 layouts the simulation of the salt yield according to the existing farming methods. It is shown on Table 3, column [D]: Method Prism Closed House could meet closely the number of 4MT raw salt yield. Total salt yield from Madura Island total ponds area is 11.000 Hectares, using Prism Closed House Method could yield 3.96 MT. Meanwhile, from national scope 26.000 Hectares of total pond’s area [33], Japanese Method [E] could yield 9.36 MT. Column A shows salt yield from Traditional Method in a year from 26.000 hectares of total national pond’s area reaching 1.56 MT. The average of salt yield from Traditional Method use is around 60 Tons per season/year [34].

### Table 3. Total Salt Yield in 2021, simulation with farming methods and Pond’s Land Wide Area

![Total Salt Yield in 2021 (Ton/Year)]
Hence, to achieve a number of 4 MT raw salt stock per year, it is needed to double the pond’s land area. This means if we choose the option: Extensification of Pond’s Land Area wide, we need to clear at least 20,000 hectares of new coastal land and transform them become new salt ponds. This is not easy to achieve, because: limited land, land use change, not all types of land can be used for salt ponds, expensive costs, long time, constrained dependence on weather, and the quality of traditional people’s salt that does not meet the requirements. Not to mention the tremendous impacts on the environment from the conversion of local natural ecological functions of coastal forests, sand dunes and so on into ponds where land and vegetation clearing will of course change the ecological function and causing the extinction of endemic local and biota. This is not sustainable and even this could change natural equilibrium, and create a disaster, environmentally, as well could decrease resiliency of coastal from natural disaster.

The proper strategy is needed to set as the base of a roadmap towards salt sufficiency. From 2 options: the extensification and the intensification, this study prefers to the intensification of salt production. This plan could be derived with several technology related ways: development of more washer plants, upgrading the washer plats, improving salts yield on site, and using more technology innovation in farming process. By technology innovation, and the use of combinative several best practice technics that have been successful in implication [35], for example, the best salt farming innovation, called: Japanese Method, combined with Salt House method, that in simulative calculation, could yield raw salt tripled (Figure 6F). It would be around 12,87 MT per year the salt yield, if most of salt farming regions start to imply method 6F: simulation of Japanese method, combined with salt house or indoor closed system. Then after achieve that 12,87 MT raw salt’s number, the effort to maximize the absorption of local industrial salt for local needs could be easier. This plan is estimated to be succeed with the support of the other intensification programs such the raw salt upgrading washer processing machines that could produce industrial salt in massive number.

3.4 The Comparison of Farming Methods and the SPH/RPG Concept

However, Table 3 is a simulation result. It is comprehensive to imply any best combination methods on totally existing ponds. Besides, the need of industrial salt in 2021 is around 3 MT. To produce this number, it is needed more than 4MT of the raw salts, in relation to the average of 20% salt loss during processing period from raw salt to become the industrial salt. Since the amount of salt production using the 6F combination methods is tripled, compared to the conventional methods, then the simulation is: it would be enough to imply the 6F combination method on 1/3 of 11,000MT total ponds on Madura Island, around 3000 hectares. In other words, the local industrial salt would be fulfilled by the development of the Japanese Method that combined with the SPH unit on each pond, on 3,000 hectares total area. This is the intensification option, that is much better solution than the option: extensification that requires 20,000 hectares new land to open for constructing the salts ponds.

This projection is based on the option: intensification of salt production. So, in this option, the land clearing to open new salt ponds area is not counted. The works to do are to multiply the existing total salt yield number to be tripled, by 2 ways: development of more washer processing plants, increase the capacity of washer plants, and supported by the industrial salt production directly on farming site. The industrial salt farming on site could be conducted using technology engineering, which in this study analysis is described as: indoor or closed system of salt house, fully technology controlled on multi variables of salt production, supported with green NRE energy for cost efficiency.

The analysis of the existing local salt farming methods is classified to 4 primary methods, on Table 3 it is shown the description of each method, plus 1 alternative method: simulation of the SPH concept. In this study, the SPH concept would be commenced based on the best simulation method: F, or Japanese Method that combined with closed system salt house. The salts house concept is called Rumah Produksi Garam (RPG) or a Salt Production House (SPH). This study is figuring many applications of science, research and technologies. Difference between the SPH and common salt house is: SPH includes salt production stages, not only the function of final stage of production: salt concentration table that protected by roof. So, the SPH combines the advantages of each method, adopting the most
productive one: method with highest number in salt yield. From study and analysis of the existing production methods using several types of technology engineering, including the acceleration of evaporation and crystallization process [36–40]. Parallel, the analysis of the existing problems would be performed, then synthesis them, resulting a concept that combining successful existing methods and also overlaying the problems with green technology-based solutions. The closed system and indoor implication would be the best choice, with the use of green NRE energy supply.

Research and design/prototyping of the Salt Production House model supporting energy efficient and environmentally friendly Salt Production with the function of increasing the quantity and quality of salt is a strategic first step to play a real role in the government's program to optimize the people's salt absorption, especially to the manufacturing industry, namely meet the supply of industrial salt. The SPH options may seem more expensive at first but can save time and money later. The closed house production method has advantages, namely: it can produce salt at any time regardless of the rainy season as well low sun ray cloudy condition. In this activity, the application of technology is more complete, in order to optimize the increase of salt quantity and quality, as well as accelerate the production of salt harvest. The SPH contains a stage of salt production, upgrading the quantity of salt production, as well as upgrading the quality of salt to industrial salt, and can continue production in a full year.

The SPH concept is designed to be more efficient in cost, effective, green or environmentally friendly, and sustainable, or low impact to the environment, because it does not require a large land area. This unit must be easy to imply and could be operated everywhere as long there is sea water available. A unit of SPH does not being attached to the IKG requirement for pond’s location, because its flooring is non-natural material. SPH is designed to fulfill all requirements in order to achieve best result in salt yield. For that, a unit of SPH should contain technology engineering’s best practices for its instrumentation. All types of successful technology interventions in salt production farming ever would be adopted, such: use of full closed indoor system for full days in a year production purpose, Baume level booster as the Japanese method’s, best roofing and flooring for speeding up process to harvest time, for increasing the quantity of salt, and increasing the quality of salt to become industrial salt. A full technology implication would be commenced since on the drainage sea water inlet system – concentration pond stage and crystallization salt table final stage.

In the next research, the design draft of an SPH unit would be drafted in DED or Detailed Engineering Design, resulting a prototype of the SPH. The SPH would be equipped with multiple sensors, computing, data storage systems, and data transfer systems in real time via the internet connection. So, data on various key variables in the salt production system can be accessed and monitored from other remote locations. The data can be immediately transferred and analyzed for special research purposes and can be further utilized as material for evaluating the production process in SPHs, for future improvements. This concept is also rich in data because many fields and components of data can be collected, for further study. The data and results of the application of the SPH concept are expected to be one of the spearheads of the skyrocketing local salt production, and the increase in the percentage of local industrial salt production, as well the basis for community development/salt environment.

The other program that is recommended to perform in order to increase number of industrial salts, which could be done by increasing the quality of raw salt, using washer processing plant. Both of these programs could be accomplished by produce this industrial salt directly during farming, parallel by the support of washer plants development program. The F method: Japanese Method that using Salt House unit is estimated could produce 1.170 Ton of Salt/hectare/year (Figure 6). By some modification and innovation, in form technology engineering could overlay the weaknesses of F method, even transform them to become the advantages. So, the salt yield could be increased more. The SPH concept is planned to be a green hybrid and self-sufficient technology-based closed system salt house method that is recommended to become a leverage factor skyrocketing the salt yield quantity, as well to improve the number of industrial salts, on farming site directly. The SPH may be called a kind of “one stop service station”, containing production stages of salt farming, as well the function of upgrading the raw salt becoming the industrial salts. By using this concept, it is estimated that the production cost of making industrial salts could be decreased.
| No | Factors                  | Components                                                                 | Methods of Salt Farming                        |
|----|--------------------------|---------------------------------------------------------------------------|------------------------------------------------|
|    |                          |                                                                           | Conventional                                   |
|    |                          |                                                                           | Tunnel, Prism                                   |
|    |                          |                                                                           | Japanese                                       |
|    |                          |                                                                           | SPH                                            |
| 1  | Location                 | type of soil                                                              | Clay                                           |
|    | IKG                      |                                                                          | Clay, geo-isolator                             |
|    |                          |                                                                           | Clay, geo-isolator                             |
|    |                          |                                                                           | technical inlet drainage, table                |
|    | Land area/ wide          | Wider = more salts, outdoor                                              | Small area, in door n outdoor                  |
|    |                          |                                                                           | Wide area, outdoor                             |
|    |                          |                                                                           | Small area, In door                            |
| 2  | Raw material sea water   | Quantity                                                                  | High amount = more salts                       |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | ditto                                          |
| 3  | Meteorology              | Rainfall                                                                  | Rainy season = no salt farming                 |
|    |                          |                                                                           | Roofed, Still producing salts                  |
|    |                          |                                                                           | Rainy season = no salt farming                 |
|    |                          |                                                                           | Roofed, In door                                |
|    | Wind                     | Stronger = better                                                        | ditto                                          |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | Conditioned wind                               |
|    | Temperature              | Higher = better                                                          | ditto                                          |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | Combined with technology                       |
|    | Humidity                 | Higher = better                                                          | ditto                                          |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | Conditioned                                    |
|    | Sunlight                 | Hotter = better                                                          | Ditto, but still low sun radiation in rainy season |
|    |                          |                                                                           | Ditto, but still low sun radiation in rainy season |
|    |                          |                                                                           | Conditioned thermal with technology            |
| 1  | Technology               | Form of drainage                                                          | thread-shaped = better then linier-shaped      |
|    |                          |                                                                           | Not always                                     |
|    |                          |                                                                           | Not always                                     |
|    |                          |                                                                           | Shorter, shortcut n bypass                     |
|    | Length of drainage       | Longer = better                                                           | Longer = better                                |
|    |                          |                                                                           | Longer = better                                |
|    |                          |                                                                           | Shorter                                        |
|    | Instrumentation          | Modern, complete and high tech = better                                   | ditto                                          |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | Full tech                                      |
| 2  | Timing                   | Duration of concentration time evaporation time                           | Longer duration                                |
|    |                          |                                                                           | Shorter duration                               |
|    |                          |                                                                           | Shorter duration with technology Intervention  |
|    | Sunny dry season         | Only in dry season farmer produce salt                                    | Every day in a year                            |
|    |                          |                                                                           | Sunny dry season                              |
|    |                          |                                                                           | Conditioned                                    |
| 3  | Human resources          | Quantity                                                                  | More = better result                           |
|    |                          |                                                                           | ditto                                          |
|    |                          |                                                                           | Instrumentation                                |
|    | Skill/experience d       | More skills = better results                                             | ditto                                          |
|    |                          |                                                                           | Instrumentation                                |
3.5 Green Energy Use
The SPH applies cost efficiency from the using of the NRE or New and Renewable Energy, namely solar and wind energy, thereby reducing fossil fuel consumption. For wind energy, one of the choices is to use vertical wind turbine or Vertical Axes Wind Turbine (VAWT) as shown on [41], and solar cell panels for the solar energy set as well [42]. The energy stock that is needed for running the SPH depends on the dimension of a unit, capacity and formation of the instrumentations used. Surely the size and specification of a unit is need to be synchronized with the existing budget. The wind turbine energy source is designed as primary source of SPH energy supply, because wind is usually still blowing at night, while solar panel would be supporting source because it is effective in daylight only [43]. This hybrid combination is estimated could supply the energy need of SPH unit, see figure 7.

The advantage of VAWT compared to HAWT or Horizontal Axis Wind Turbine is the VAWT could gain more energy from its design [41,42]. VAWT has wider form of propeller, and its position is on open air, so this condition could catch wind more effective. These advantages are supported with coastal weather condition, that usually having strong wind blow [41], so that the energy produced would be greater and long-lasting as well. This is equal to the green and sustainable energy use and is according to SDG’s direction. The energy efficiency would be very significant, it is identic of the cost efficiency, because the electricity need to activate the instruments would be supplied totally by the free energy use.

![Figure 7. A. Types of wind turbine energy that would be used in SPH concept [41],[B. Solar Panels [PersonalDocumentation]]

The form of SPH’s closed system could be a cube that covered with transparent glass. Its dimension depends on the type needed on each location, as well on the budget availability. It is estimated that a glass green house would be better, with more advantages [42].

3.6 Novelty and Breakthrough Research
The SPH unit is a concept that is designed in a ready-to-use program that has a function and can play a major role in the national program to increase the local salt production to meet 84% of industrial salt
needs. The type of the SPH is the intensification of salt production, so it does not require more land to open new ponds, but its work is to improve the salt yield from the existing ponds, by using multi variables technology engineering. This concept is designed also to provide real time data on the specific conditions of each stage in the salt production cycle, especially the evaporation rate data in salt ponds that can be accessed online. So that it can be monitored what variables are obstacles as well as knowing the supporting variables, which are useful in further efforts to improve the performance of SPH units.

4. Conclusion
The study concludes that number of salt yield: raw salts and industrial salts as well could be improved in significant faster works, lower cost, and with no massive impact to the environment, by preferring the option: the intensification of salt production. There are ways in the intensification option: development of more washer machines, upgrading the capacity of washer machines, improving more raw salt yield on the existing ponds, as well producing industrial salt on site, on farming location. For improving the raw salt and the industrial salt yield as well, the priority method that is recommended for this work are the Japanese Method that combined with Salt House closed system. This study recommends the SPH closed salt house concept, that would be best to imply on the existing salt ponds. The other crucial different between the option: extensification and the intensification is: the extensification of salt ponds is a disaster for the environment, because it requires massive 20.000 hectares of new land clearing to open new salt ponds. While the intensification, especially the recommended combination methods: salt farming ponds that implying the Japanese Method and the SPH closed house system, would require around only 3.000 hectares of the existing salt ponds. So, this method requires no new land clearing: an environmentally friendly and low-cost method.

Recommendations
It is needed the proper strategy action to improve salt number, to fulfill salt needs: to set as the base of a roadmap towards salt sufficiency. From 2 options: the extensification and the intensification, this study prefers to the intensification of salt production. This plan could be derived with several technology related ways: development of more washer plants, upgrading the washer plats, improving salts yield on site, and using more technology innovation in farming process. By technology innovation, and the use of combinative several best practice technics that have been successful in implication, for example, the best salt farming innovation, called: Japanese Method, combined with Salt House method. Then the SPH, is more updated method that could be run better, by overlaying the Japanese Method’s weaknesses, and transform them to be advantages. So, the recommendation is to realize the existing Japanese Method in Pamekasan Regency, Madura Island, combined with Salt House method, and also develop the prototype of the SPH.

The green house with glass is most suitable option to build an SPH. The optimum achievement would come from the combination of the Japanese Method and the SPH, that implicated on each of the existing farm ponds, that also imply the advanced method, for example the Australian method. Table 3E shows the simulation of the Japanese Method use that could achieve 4,29MT of raw salt per year, this number is more than twice of the existing local raw salt production in 2021. And that 4,29MT of raw salt could be achieved if the Japanese Method are implied on totally 11,000 hectares of ponds at Madura Island. But, using the combination of The Japanese Method and the SPH concept, it is needed only 3,000Hectares of the existing salt ponds to produce more than 4MT raw salts to be processed to become the nearly 100% of 3MT industrial salts.

The prototype of the SPH unit would be constructed after the study program of SPH DED/ Detailed Engineering Design. The advantages of SPH concept in energy: each unit is supported with the non-fossil energy, that green and sustainable energy use, consuming wind and solar energy, and is according to SDG’s direction. So, there is also an efficiency of cost, that parallel to the type of the energy consumption. The use of fossil fuel is known as a high-cost activity. By using the free wind and solar energy, the efficiency could reach up to 50%. For future researches: it is needed a sequel of this research detailing the design that resulting a draft of an SPH, completely with its instrumentations and the green
energy use. Then, the final program would be: the implementation stage, constructing a prototype of the SPH, run it and do the evaluation. Many technology aspects could be implemented in SPH in order to optimize the salt production, whether it is chemical or physic engineering.

References

[1]. Khayam, M. 2021. Director General of Industry, Chemical, Pharmacy and Textile, Ministry Of Industry, Indonesia. https://www.jawapos.com/ekonomi/12/02/2021/kebutuhan-garam-nasional-tahun-ini-ditaksir-capai-46-juta-ton/
[2]. Khayam, M. 2021. Director General of Industry, Chemical, Pharmacy and Textile, Ministry Of Industry, Indonesia. https://ekonomi.bisnis.com/read/20210210/257/1354875/kemenperin-sebut-kebutuhan-garam-industri-2021-capai-38-juta
[3]. Ministry of Industry (Kemenperin), Indonesia. https://kemenperin.go.id/artikel/22372/Kemenperin-Dukung-Target-Penyeraan-Garam-Lokal-Hingga-1,5-Juta-Ton-di-2021
[4]. Ministry of Industry (Kemenperin), Indonesia. https://tri.co.id/ekonomi/974830/kemenperin-janji-serap-garam-lokal-untuk-kebutuhan-industri
[5]. Tanduk, T. 2021. Chief of AIPGI, https://www.jawapos.com/ekonomi/12/02/2021/kebutuhan-garam-nasional-tahun-ini-ditaksir-capai-46-juta-ton/
[6]. Burhanuddin, S. 2020. Deputy of Maritime Resources Coordination, Kemenkomarves, Coordinating Ministry for Maritime and Investment, Indonesia. https://maritim.go.id/pemerintah-bahas-berbagai-upaya-tingkatkan-produksi-garam-nasional/
[7]. Ministry of Maritime Affairs and Fisheries, Indonesia. 2021. www.kkp.go.id
[8]. Kemenkomarves, Coordinating Ministry for Maritime and Investment, Indonesia. www.maritime.go.id
[9]. Burhanuddin, S. Deputy of Maritime Resources Coordination, Kemenkomarves, Coordinating Ministry for Maritime and Investment, Indonesia. https://ekonomi.bisnis.com/read/20210126/99/1348305/kemenko-marves-targetkan-produksi-garam-nasional-31-juta-ton-pada-2021
[10]. The Agency for Research and Applied Technology, Indonesia. https://www.bppt.go.id/
[11]. PT Garam enterprise. https://www.ptgaram.com/
[12]. Widjaya, S. Chief of Research Agency for Maritime Affairs Ministry of Maritime Affairs, Indonesia. https://www.suarasurabaya.net/kelanakota/2021/perlu-pemetaan-tambak-garam-dipulau-madura/
[13]. The Agency for Research and Applied Technology, Indonesia. https://www.bppt.go.id/
[14]. Lukman, A. S. 2021. Chief of GAPMMI. https://gapmmi.id/
[15]. Gemilang, W., S., Wisha, U., J., Kusumah G. 2019. Identification of Groundwater Contaminated by CI - Pollutant in Salt Pond Pademawu Sub-District, Pamekasan, Madura, Using Specific Resistance Geo-Electricity Method. Journal of The Environmental Technology Vol. 20, No 1, Januari 2019
[16]. Hanik, U., Mutmainah. 2020. Performance and Need Analysis of Salt Farmers in Pamekasan Regency as a Based of Development of the Design of Social Learning Model. Social Economy Jounal of Maritime and Fisheries, vol. 15 no. 2 Desember 2020: 237-249.
[17]. Dick, W., & Carey, L. 1996. The systematic design of instruction (4th ed.). New York: Harper Collins College Publisher.
[18]. Branch, R. M. (2009). Instructional Design: The ADDIE Approach. New York: Springer Publishing.
[19]. Purbani, D. 2006. Process of Salt Crystal Construction. Research Center for Maritime, KKP.
[20]. Course of Salt Production Improvement using Tunnel System. https://www.puslat.kkp.go.id/puslatweb/berita.php?mod=view&id=NWID000559
[21]. Central java Province. https://jatengprov.go.id/beritadaerah/tambak-garam-desa-bunton-jadi-percontohan-model-tunnel/

[22]. Kurniawan, A., Jaziri, A. A., Amin, A. A. & Salamah, L. N. 2019. Indeks Kesesuaian Garam (IKG) untuk Menentukan Kesesuaian Lokasi Produksi Garam; Analisis Lokasi Produksi Garamdi Kabupaten Tuban dan Kabupaten Probolinggo. Journal of Fisheries and Marine Research, 3(2), 236-244. https://doi.org/10.21776/ub.jfmr.2019.003.0.2.14

[23]. Kurniawan, A., Lestariadi, R. A., Kurniaty, R., Prayogo, T.B., Dewi, C., S. U., Amin, A. A., Yanuar, A. T., Salamah, L.N. 2020. The Analysis of the Salt Location Suitability Index (IKG) in the Salt Production Center of East Java Province. DOI: https://doi.org/10.21107/rekayasa.v13i3.9130.

[24]. Bramawanto, R, Sagala S. L., Suheimi I. R., & Prihatno, H. 2015. Structure and Composition of Salt Pond Using Filtering Threaded Technology to Increasing Salt Production. Jurnal Segara, 11:1-11

[25]. Maulizula, A, Suryadi, Murdani. 2016. Factors Affecting Salt Production in Seunuddon District, North Aceh Regency, Indonesia. Jurnal of Aqirfo • Vol. 1 • No. 1 • April 2016

[26]. Suhendra A. 2016. Increasing The Productivity of Salt Trought HDPE Geomembrane IndonesiaCase History in Salt Evaporation Pond. EJGE, 11, 4272- 4280

[27]. Kurniawan, A, Assafri,F., Munandar, M.A., Aziz A. J., Asep A P., Guntur. 2019. Analysis of Sea Salt Quality from the Green House Prism Method in Lawas Village, Sedayu, Lamongan, East Java Province. National Journal of Maritime, Vol. 14, No 2, Agustus 2019, Hal. 95-102. DOI: http://dx.doi.org/10.15578/jkn.v14i2.7073

[28]. Kumala, A. (2012). Analysis of the Effect of Rainfall on Salt Productivity (Case Study: Salting I Sumenep, PT. Garam (Persero)). Thesis, PT. Garam (Persero)). Skripsi. Institut Pertanian Bogor: Bogor.

[29]. Nasir, M. 2018. Minister of Research and Technology https://risbang.ristekbrin.go.id/publikasi/berita-media/tambak-garam-tahan-cuaca-dan-bertechnologi-canggih-dibangun-di-pamekasan/

[30]. Salim, Z., Munad, E. 2016. Salt Commodity Info, Jakarta: The Agency for Research andDevelopment of Trade, Ministry of Trade, Indonesia. Al Mawardi Prima Press. Accessed on July 3 2020 dari http://bppp.kemendag.go.id/media_content/2017/08/lsi_BRIK_Garam.pdf

[31]. Ministry of Maritime Affairs, Indonesia, Directorate General of Coastal and Small Islands. 2011. Salt’s Self-Sufficient National Program. Accessed on 20 July 2021, dari https://jdih.kkp.go.id/peraturan/35-permen-kp-2014.pdf

[32]. Ministry of Industry Indonesia. 2015. Government will Keep Import Salt. Cited from https://www.kemenperin.go.id (accessed on December 4, 2018).

[33]. Ministry of Maritime Affairs and Fisheries Indonesia.2015. Salt Production in Indonesia. Cited from https://statistik.kkp.go.id (accessed on December 4, 2020).

[34]. Susanto, H., Rokhadi, N., & Santoso, G.W. (2015). Development of Traditional Salt Production Process for Improving Product Quality dan Quality in Jepara District, Central Java, Indonesia. Proceeding Environmental Science. 23, 175-178.

[35]. Soemargono, Widodo, L.U. 2018. Method of speeding up salt production. Journal of Chemical Engineering, UPN Veteran University, Surabaya, East Java, Vol 12 No 2, April 2018 http://ejournal.upnijatim.ac.id/index.php/tekkim/article/view/1089

[36]. Rositawati, A. L., Taslim, C. M., & Soetrisno, D. (2013). Recrystallization of People’s Salt at Demak Regency to achieve Industrial SNI Standard. Journal of Chemical Technology and Industry., 2(4), 217-225

[37]. Umam, F. 2019. Refinery of Salt using Recrystallization Method at Bunder Village, Pamekasan Regency, East Java, to achieve Table Salt SNI Standard. Journal Science Pangabdhi 5(1), 24- 27.

[38]. Sulistyawiningsih, T., Sugio, W., & Sedyawati, S.M.R. 2010. Table Salt Refinery using Crystallization of High Concentrated Brine Water with Impurity Separator Na2C2O4 -
NAHCO3 dan NA2 C2 O4 - NA2 CO3. Journal of Science dan Technology, 8, 26-33

[39]. Wiraningtyas, A., Sandi, A., & Ruslan, R. (2019, May 21). Iodized Salt Processing Technology through Solar Thermal Salt House in Sanolo Village. *MITRA: Jurnal Pemberdayaan Masyarakat*, 3(1), 1-10. https://doi.org/https://doi.org/10.25170/mitra.v3i1.494

[40]. Aji, A. G. S. 2013. The Influence of Opening on Roof and Current Valve in Salt Maker to Volume of Sea Slat. Final Assignment, Bachelor of Mechanical Engineering, University of Sanata Dharma, Yogyakarta, Indonesia.

[41]. Castellani f, Astolfi d, Peppoloni m, Natili F, Buttà d, Hirschl a. 2019. Experimental Vibration Analysis of a Small Scale Vertical Wind Energy System for Residential Use. *Machines* 2019, 7, 35; doi:10.3390/machines7020035. *Machines | An Open Access Journal from MDPI*.

[42]. Sethi, V.P. (2009). On the selection of shape and orientation of a greenhouse: Thermal modeling and experimental validation. Solar Energy, 83, 21-38

[43]. Hidayat, R. 2011. Design and Construction of Salt and Fresh Water Divider using Solar Energy Thesis, Bogor Institute of Agriculture.

**Acknowledgement**
This research is funded by DIPA APBN for Marine Research Center of KKP Indonesia.