Hybridization of Concentrated Solar Power with Biomass Gasification in Pakistan

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**Key words:** Concentrated Solar Power (CSP), biomass gasification, parabolic trough tracking system, development, sustainable

**Abstract:** Using renewable energy to address energy crisis is the only way Pakistan can achieve its millennium development goals and sustainable economic development. The lack of energy affects not only the economy but also other sectors such as education, health and economy. The energy deficiency in Pakistan has a serious impact on education, students training in laboratories and classrooms and wastage of time, the most deleterious. The objective of this study is to propose and analyze different hybridization techniques like gasification of concentrated solar power and biomass for energy generation. Gasification of CSP-biomass hybrid plant is innovative concept that allows the integration of combined cycle for power generation. For this research different heat transfer fluids in a receiver like molten salt, terminal VP-1, Hitec and patterned their conversion efficiency besides comparing electricity production of two cities Karachi and Quetta. Although, direct normal irradiance in Quetta is comparatively high (2301 kW m$^{-2}$) than Karachi (1576 kW m$^{-2}$) but solid waste production from Karachi is better, i.e., 9000 tons then Quetta, i.e., 326 tons with over all solid waste production of 71000 tons from big cities of Pakistan. My proposed model favor parabolic trough for generation of electricity using Hitec in place of molten salt as a heat transfer fluid in receiver tube. Also, we selected Karachi over Quetta because for modeling of hybridization both copious waste products and Hitec as renewable energy resources are necessary.

**INTRODUCTION**

Pakistan has been suffering from electrical energy crises, since, independence. These crises are not due to the non-availability of energy resources. The problem, we face today as a nation that how to generate electrical energy from energy resources. There are multiple ways such as the generation of electrical power from sun, water, wind, concentrated solar power and biomass to solve this major issue. A combined biomass and concentrated solar power uses two energy sources with a flexible output that depends on weather conditions and availability of resources. For hybridizing, a different combination of renewable energy resources is used such as biomass with solar power plant, biomass with hydro-power plant, biomass with the wind, biomass with geothermal, biomass...
with photovoltaic and biomass with parabolic trough. Hybridization of biomass with concentrated solar power (Milani et al., 2017) for power generation through gasification processes. Hybridization of a CSP-biomass plant through gasification is an advanced idea that permits the addition of joint cycles for power generation, hybridization of solar biomass and storing of synthesis gas (GOP., 2013) discover different technologies of solar which is right for simulation of hybridization with biomass for shared Heat and Power (CHP) generation in Europe. His analysis of practical and financial research shows that the hybrid system in order to calculate the actual and financial viability of the project is in growing stage. He used three different combinations of solar energy technologies and biomass: Parabolic Trough (PT)-biomass and Linear Fresnel (LF)-biomass systems, Solar Tower (ST)-biomass. According to researcher the most suitable technology for hybridization is CSP with rankin cycle power plants using conventional fossil fuel like coal, natural gas and waste material (Peterseim et al., 2013; Soria et al., 2015) solar energy, originally the hybrid biomass plant in Spain and a combination of two energy sources is committed to reducing business investment. The evaluation examined the configuration of seventeen hybrids focused on solar energy, biomass in terms of technical, economic and environmental efficiency. The combination of thermal loads of the bronze salt is considered for the most efficient hybrid configuration. The combination of thermal loads of the bronze salt is considered for the most efficient hybrid configuration. While heat storage can significantly increase the production of the plant, even up to 7 h of installation, the fully charged load will generate the largest amount of electricity from 70% of the biomass (Peterseim et al., 2014a, b). Focusing on solar energy hybrids of biomass plants has become an even more interesting and economical alternative for the proven distribution of non-conventional resources, the first plant has started its work activity at the end of 2012 with capacity of 22.5 MW in Spain (Peterseim et al., 2014a, b). Suggested that the concept of synthetic fuel from solar biomass production uses the approach as an important source of energy. The goal is to provide a simple idea of a treatment with almost zero emissions of CO₂ emissions reduction and matched to first and second generation biofuels. One of the main features of this concept is the use of high temperatures of a solar cell to activate the conversion process of biofuels as biofuels; the output is used almost exclusively by carbon atoms. The analysis of H₂ water electricity with solar energy issued to reverse inverse gases in order to avoid CO₂ production during this process. The modeling of chemical processes is the solar biofuel, compared to two other concepts of high quality synthetic oils second-generation liquid biofuels and the use of coal technology and emissions and CO₂ emissions have created storage in the industry oil. The third generation of biofuel controlled with biomass needs only 33% of the biomass input and 38% of the total amount of the Earth, a second generation biofuel at the same time, which shows neutral neutron CO₂. With the second generation of CO₂ emissions, the second generation will take 50% of carbon dioxide from the atmosphere (Peterseim et al., 2014a, b). A system to generate energy from biomass, using biogas and generating solar thermal energy has analyzed the practice of the fluidized bubbling bed system using a mixture of CO₂-H₂O-O₂ and CSTP through brass. BFG simulates a semi kinetic model using the Continuous Reactor (CSTR) prototype for cradle behavior and a Plug Flow Reactor (PFR) Model. In (Hertwich and Zhang, 2009) explored the hybrid system of solar generation and biomass energy. It was believed that the integration of heat transfer networks is a useful method for combining biomass and solar energy (Tanaka et al., 2014). Proposed a new solar system with a biomass energy generation that combines two phases of gas production. In this system, there are two different types of solar collectors, focusing on solar heat at different temperatures used to stimulate the biochemical pyrolysis process called thermo chemical sun (at about 643 k) and gas (if the temperature around 1150 k) for the fuel solar generation, solar energy, gas syngas is used directly to combine an improvement cycle to generate electricity. Hybrid system is system that can be used completely with renewable energy resources and they can provide a fit atmosphere. The concentrated solar power itself can have positive impact on the rural economy and it can provide with a fresh and clean atmosphere. The use of hybrid system is the only way to tackle the current energy crises and also to maintain and develop a sustainable economy.

**Mathematical modeling of parabolic trough:** The parabolic collector is basically linear focus collector with composition of cylindrical curved parabolic mirrors which reflects sunlight with in a tubular receiver situated in the focusing line of the parabolic collector. The tubular receiver bears a fluid, absorbing heat and transferring it via. the circulation to the boiler or such other device to help produce steam (Coelho et al., 2015). The rows of parabolic mirrors are adjusted in parallel fashion on a North-South axis (typical) or on an East-West axis (there are pros and cons for each orientation depending on the location and energy production requirements) in order to get maximum of sun radiations. The tubes are specifically, designed to absorb solar radiations and thus transfer heat to the heat transfer fluid which moves through the tube (Bai et al., 2017). The fluid is then pumped through the absorbent tubes which are connected in series and in parallel manner. Some systems are provided with an isolated storage tank and heat transfer fluid is directed through the storage tank if present and then rushed into the heat exchangers to transfer the heat to the water to generate steam and expand it into a steam turbine for generation of electricity.
Fig. 1: Solar tracking mount (Tanaka et al., 2015)

**Components of power plant:** Concentrated solar power plant consists of following components:

- Collecting and tracking system
- Energy conversion system

**Collecting and tracking system:** Collecting and tracking system direct and concentrate solar radiation and convert it into thermal energy. It consists of parabolic trough collector and tracking system. Solar radiation is collected by parabolic trough and converted into thermal energy. Tracking system consists of two self-determining tracking axes to rotate in the horizontal plane and another to rotate vertically. The concentration of sunlight using solar installation is shown in Fig. 1.

**Parabolic trough concentrator:** The Parabolic Concentrator (PC) Concentration Ratio (CR) is given by Eq. 1 (Cau and Cocco, 2014):

\[
\text{CR} = \frac{A_r}{A_c}
\]

Where:
- CR : The ratio of \( A_r \) to \( A_c \)
- \( A_r \) : The receiver area
- \( A_c \) : The projected area of the concentrator

If higher the concentration ratio, the extreme temperatures will be higher. Getting high temperatures is a feature of PT. In order, the final temperature reached by the concentrator is the temperature of the source. Equation 2 provides a PT absorbency map which ignores the design and measurement:

\[
T_{abs} = T_s \left[ (1-\eta) + \frac{\text{eta}_{abs}}{\varepsilon_{abs}} \times \text{CR} \times \sin^2 \theta \right]^{\frac{1}{2}}
\]

The subsequent values are given:
- \( T_s \) : Source temperature (k)
- \( \varepsilon_{abs} \) : Emissivity of absorber
- \( \eta \) : Efficiency of moving heat to operational fluid
- \( \text{eta}_{opt} \) : Optical efficiency of concentrator structure

**Reflection:** Emission of EM waves and other lights can be reached in many methods. It may reflect the transfer of material that is not effective or is absorbed by the surface.

With EM absorption waves increase the energy of the pressure surface. Equation 3 defines a specific surface that depends on its.

Each of these factors defines the result of the surface affect on the radiation that influences it. For example, the area width = 1 will pass entire radiation over the material and no one will be absorbed or reflect. Material conversion factors are based on radiation, surface temperature and angle of fall. For a simple analysis, the coefficients are means for the areas of interest and a value is given:

\[
\tau + \rho + \gamma = 1
\]

Where:
- \( \rho \) : Reflection coefficient
- \( \gamma \) : Absorption
- \( \tau \) : Transmittance

**Focal point:** A parabola is a curve generated by the intersection of a right circular cone and a plane parallel to an element of the curve. Equation 4 describes a parabola that is symmetric about the y-axis:

\[
y = ax^2
\]

Electromagnetic waves as a symmetrical axis cuts off the point called a focus or focal point:

\[
f = \frac{1}{4a}
\]

**Optical efficiency:** The best concentrator focuses all the light that strikes its surface at one point. In fact, the error in light of dish skew light glass, increase the size of the beam (Chakravarthi, 1997). The overall error of the angles, due to the optics can be considered using Eq. 6:

\[
\sigma_{tot} = \sqrt{(2\sigma_{con} \sigma_{tracking}) \sigma_{conc} \sigma_{Ref} \sigma_{abs}}
\]

While angular errors are:
- \( \sigma_{tot} \) : Sun’s rays not exist perfectly parallel
- \( \sigma_{tracking} \) : Concentrator arrangement with sun
- \( \sigma_{conc} \) : Concentrator surface loopholes
- \( \sigma_{Ref} \) : Non specular reflector
- \( \sigma_{abs} \) : Focal point arrangement with receiver

We clearly define the fractional fraction, the flow capture element that reflects the percentage of light returned in the preferred circle of intersection with diameter (d). Equation 6 provides the value of the fraction:

\[
\Gamma = 1 - 2Q_s
\]

While:
- \( Q_s = f_{x1}(b_1^x t^x + b_2^x t^x + b_3^x t^x + b_4^x t^x + b_5^x t^x)
\]
Where:

\[ f_s = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \]  

(9)

\[ t = \frac{1}{(1+r+x)} \]  

(10)

\[ x = \frac{n}{2} \]  

(11)

\[ n = \tan^{-1}\left( d \cos \phi \right) \left( \frac{2}{\sigma_{\text{int}}} \right) \]  

(12)

And values of parameter is given that:

\[ r = 0.3316419 \]

b : Constant parameter and depends upon location:

\begin{align*}
b_1 & = 0.479381530 \\
b_2 & = -0.456563782 \\
b_3 & = 1.881477937 \\
b_4 & = -1.721255978 \\
b_5 & = 1.430274429 \\
d & : Diameter of receiver \\
\phi & : Rim angle \\
\rho & : Space from focal point to rim of the paraboloid
\end{align*}

The standard error of the angles is found in the modern paraboloid concentrators (\( \sigma \)) at 6.7 mrad (Gu et al., 2009). This causes a step factor from 1 to a diameter of 4.8 inches. This means that 100\% of the radiation reflects a 4.8 inch round surface. As the total error increases, a depth diameter is required to capture the same amount of radiation. The optical efficiency of the concentrator system (\( \eta_{\text{opt}} \)) defines the ability of CPCs to absorb and reflect solar radiation. Optical efficiency is a product of reflection efficiency \( \eta_{\text{Ref}} \) and radiation absorption for recipient \( \eta_{\text{abs}} \). This effect is shown in Eq. 13:

\[ \eta_{\text{opt}} = \eta_{\text{Ref}} \times \eta_{\text{abs}} \]  

(13)

The perfect systems will reflect the center equivalent to 1 and the absorption coefficient will be equal to 1 reflection it absorbs a small amount of radiation and absorbs radiation which can reduce system efficiency. The combination of optical performance with the flux capture fraction ensures collection efficiency. The effectiveness of the collection describes the ability of the CPC to collect the radiation available and absorbed by the radiation in the receiver. The efficiency of the collection was developed using Eq. 14:

\[ \eta_{\text{collection}} = \eta_{\text{opt}} \times \Gamma \]  

(14)

Receiver design: The receiver is part of the system that converts the sun’s radiation into a working liquid. The receiver has heat absorbers and heaters. Absorbent as a pressure surface to reflect solar radiation. The rays are absorbed into absorbent material (Yanning et al., 2009; Gupta et al., 2008; Celli et al., 2008). The heat exchanger transfers energy to the working fluid that sends energy from receiver. Equation 15 shows the energy balance for the recipient:

\[ Q_{\text{out}} = Q_{\text{abs}} - Q_{\text{loss}} \]  

(15)

Where:

\[ Q_{\text{out}} : \text{Transferred of useful energy to working fluid} \]

\[ Q_{\text{abs}} : \text{Energy composed by the absorber} \]

\[ Q_{\text{loss}} : \text{Energy losses of receiver} \]

The total receiver efficiency \( \eta_{\text{rec}} \) is given by Eq. 16:

\[ \eta_{\text{rec}} = \frac{Q_{\text{out}}}{Q_{\text{abs}}} \]  

(16)

Absorber: There are two types of absorbers exterior and cavity. Extracurricular absorption is more in the plate. Radiation is reflected in the holes and in the heat of the surface. The external drawer is simple and cheap but it does not work (Coleman, 1989). The external absorption is openly exposed to the surrounding air and at high temperatures the loss of collection can be strong. The temperature distribution will also occur in the recipient. With all the heat, only one end of the internal temperature receiver will vary dependent on the distance from absorber to the surface. As a result, the efficiency of the heat exchanger can be reduced (Luo et al., 2015; Antonelli et al., 2015). Absorbing external vapors if any ray reflects on the surface of the earth it is reflected in absorption and loss. These problems can be reduced by using cosmetics. The absorption device will be configured in the receiver. The sun’s rays are reflected by concentrating on the so-called receiver opening and are collected on the absorption surface. The most current receivers have this type. Coils are costlier and more complex than external absorbers but they are very effective. If any ray reflects the absorbent surface it affects other parts of the absorbent material. In this way, it absorbs more chances to absorb radiation when light directly on the surface. This effect is measured in Eq. 17.

If we raise the pointer within 5 times the depth and absorb 0.7, the absorption efficiency willing crease to 0.92. Absorb the cavity effectively is superior to the bag:

\[ a_{\text{eff}} = \frac{a_s}{a_s + (1-a_s)^2 \frac{A_t}{A_s}} \]  

(17)

The recipient is isolated with the exception of the observer. As the size of the absorber increases, the energy absorbed by the concentration increases as indicated by the focal point. However in this case, a thermal loss
to the environment also increases. Equation 18 is used to optimize the size of the observer. In this equation, absorbed radiation \(Q_{in}\) is the function of the normal absorption diameter of “L” and the angular error concentrator “G”. Energy loss \(Q_{loss}\) is primarily a function of the diameter of the absorbent mass.

\[
Q_{in} = Q_{in}(L, G) - Q_{loss}(L)
\]  

(18)

Heat transfer: Most of the heat exchanges in the concentrated collection systems are obtained from the receiver. Solar energy is reflected in the absorption and release of the system through the working fluid and the loss of heat. Heat is lost through three heat transfers; Current radiation and vibration Eq. 19 provides the thermal efficiency of the collection system \(\eta_{therm}\).

\[
\eta_{therm} = \frac{Q_{in}}{Q_{in}} = 1 - \frac{Q_{loss}}{Q_{in}}
\]  

(19)

Where:
\[
Q_{in} = Q_{out} - I
\]  

(20)

\[
Q_{in} = Q_{out} + Q_{conv} + Q_{cond}
\]  

(21)

Where:
\(Q_{in}\): Incident energy on dish
\(I\): Direct normal insolation
\(Q_{out}\): Absorbed energy by working fluid

Energy conversion system: Energy conversion system convert thermal energy into steam energy and steam energy is converted into kinetic energy and kinetic energy is converted into electrical energy. The electrical energy is the final product of the solar power plant. There are two main ways of transmitting heat to an energy source: first, a superior functional HTF from which heat is displaced to the working fluid of the rankine cycle (water) or secondly, steam is generated for the rankine cycle in the parabolic channel absorber tubes and transported to the turbine. The first version is called indirect steam generation and the second version is called direct steam generation. Indirect steam generation power plants include two fluid cycles, one heat transfer fluid cycle and second is rankine cycle. The thermal connection between them is carried out in a steam generator train which consists of an economizer (preheating of the water supply) an evaporator and a super heater. The direct steam generation plants in the opposition contain only one fluid cycle which is actually called steam cycle. Figure 2 shows the indirect generation of steam and Fig. 3 shows the direct generation of steam.

Heat can be stored in sockets to make heat transfer from the damper. When electricity in the cloud stops supplying energy to the system, flowing fluids can gain energy from accumulated heat. The amount of energy stored is proportional to the temperature increase and heat capacity. The total energy stored in the moving material is shown in Eq. 22:

\[
Q_{s} = m[C_{solid}(T^{*}-T1) + \lambda + C_{liquid}(T2-T^{*})]
\]  

(22)

Where:
\(Q_{s}\): Energy stored
\(m\): Mass of material
\(C_{solid}\): Heat capacity at solid phase
\(C_{liquid}\): The heat capacity at liquid phase
\(T1\): Temperature of initial material
\(T2\): Temperature of final material
\(T^{*}\): Phase change temperature

MATERIALS AND METHODS

This research proposes the hybridization of CSP and biomass for Pakistan. The power plant is model and simulated using the System Advisor Model (SAM), being an Integrated Solar Gasification Combined Cycles (ISGCC). ISGCC can be considered as conventional Integrated Gasification Combined Cycle (IGCC). The difference between ISGCC and IGCC is in the primary energy source where ISGCCs is not only a source of gas but also solar power. It is important to show that all ISGCCs use ecosystems and CSP parabolic trough technology. Figure 4 it is likely to recognize three
Blogs 

Gasification 

HTF (heat carrier) 

Rankine cycle 

Steam generation 

Turbine generator 

Fig. 4: Block diagram of hybrid system

practices in ISGCC. The first cycle, the yellow is the cycle of gas where the biogas produces gasoline which is burnt in a Gas Turbine (GT) and then moved to rankine cycle. Heat is carried from CSP by HTF to rankine cycle and then from rankine cycle to the steam generator. And this steam is used as mechanical energy in turbine generator to generate electricity. The hybridization block diagram is shown in Fig. 4.

Choice of gasification technology: There are three key gasification technologies, first the fixed bed, second entrained flow and third fluidized bed (bubbling BFB and circulating CFB). The heat necessary for the procedure can be delivered in two ways, indirectly and directly (Ruiz et al., 2013; Dascomb, 2009). Numerous readings (Dascomb, 2009; Alauddin et al., 2010) show that the indirect reactor is more preferable for biomass gasification over a direct reactor due to change rate and the high heating value of syn gas produced by direct reactor. The gasifier, although, defined is not simulated in this study because the attention of the current study lies in the simulation of PT by using System Advisor Model (SAM) for the hybridization prospects between CSP and biomass and not in describing gasifier simulation in AspenTech simulation.

RESULTS AND DISCUSSION

The simulation of PT through SAM and data collection two experiments that were performed for the proposed hierarchical system is given below.

Simulation of PT through SAM: Before going to simulation processes, area of selection is very important. For hybridization select those areas where DNI is high and also waste material is high. In Pakistan DNI in Quetta is high about 2301 kWh m\(^{-2}\) and in Karachi DNI is 1576 kWh m\(^{-2}\). For hybridization CSP and biomass both are compulsory. Karachi population is about 15 million while Quetta has only 1.001 million (Alauddin et al., 2010; Book, 2003) show in Fig. 6. And Government of Pakistan (GOP) guesses that 71,000 tons of solid waste is generated per day, mostly from major metropolitan areas. Karachi, Pakistan’s largest city generates more than 9,000 tons of municipal waste daily and Quetta has generated only 326 tons of Municipal waste. So, select Karachi because it is best option for hybridization. The population of different city and DNI of different city show in Fig. 6 and 7, respectively. SAM uses the time zone, elevation, latitude and longitude to calculate the sun position during simulations. It does not use the city; state, country and other descriptive information the Table 1 show the zone, elevation etc.
Data collection: It is vital to know how to arrange the loop of receiver and collector by using SAM shown in Fig. 6, keeping in view the important components like solar field, collectors, receivers, power cycle, thermal storage, system cost and lifetime as following. Each square in the diagram denotes a collector-receiver assembly. The color of the square and SCA number shows the collector type of each assembly. Likewise, the color of the line demonstrating the receiver and the HCE number shows the receiver type. The “DF” number shows the collector de-focusing order. SAM permits you to identify a single loop of up to 35 collector-receiver assemblies, and up to four unalike receiver and collector types.

Identify solar field parameter and minimum in let temperature and maximum outlet temperature for simulation of PT to give full efficiency which is given below in Table 2-6. Similarly collector, receiver, power cycle and thermal storage parameters are given.

Table 1: Climate data of Karachi Pakistan (SAM 2017)

| Parameters                      | Values                  |
|---------------------------------|-------------------------|
| **Location and resources**      |                         |
| City                            | Karachi                 |
| State                           | Sindh                   |
| Time zone                       | UTC+5                   |
| Elevation                       | 22                      |
| Latitude                        | 24.90 N                 |
| Longitude                       | 67.13 E                 |
| Average DNI                     | 15.76 kW m\(^{-2}\)     |
| **Climate data**                |                         |
| Global irradiation              | 1962 kW m\(^{-2}\)      |
| Dry bulb temperature            |                         |
| Wind speed                      | 5.8 m sec\(^{-1}\)      |
| Terminal velocity               | [0.36, 4.97] m sec\(^{-1}\) |

Table 2: Solar field parameter

| Solar field                  | Type | Value | Unit   |
|-------------------------------|------|-------|--------|
| Field HTF fluid               | Hitec| -     | -      |
| Inte temp                     | -    | 190° C|        |
| Exit temp                     | -    | 500° C|        |
| Min single loop flow rate     | -    | 1.75  | kg sec\(^{-1}\) |
| Max single loop flow rate     | -    | 12.8  | kg sec\(^{-1}\) |
| Terminal velocity             | VP-1 | [0.36, 4.97] | m sec\(^{-1}\) |

Fig. 6: Population of Pakistan

Fig. 7: Direct normal irradiance of Pakistani cites
Table 3: Collector parameter

| Collectors (SCAs) | Solargenix SGX-1 | Values | Units |
|------------------|-------------------|--------|-------|
| Reflective aperture area | - | 656 | m² |
| Aperture width | - | 6 | m |
| Length of collector assembly | - | 115 | m |

Table 4: Receiver parameter

| Receiver | Shott PTR80 | Values | Units |
|----------|-------------|--------|-------|
| Absorber tube inner diameter | - | 0.076 | m |
| Absorber tube outer diameter | - | 0.8 | m |
| Absorber flow pattern | Tube flow | - | - |
| Internal surface roughness | - | 4.5e-05 | - |
| Annulus gas type | Air | - | - |
| Estimated average heat losses | - | [310, 590, 4518, 0] | - |

Table 5: Power cycle parameter

| Power cycle parameter | Values | Units |
|-----------------------|--------|-------|
| Estimated output (Nameplate) | 150 | Mwe |
| Rated cycle conversion efficiency | 62% | - |
| Aux heater outlet set temp | 391°C | C |
| Minimum required startup temp | 300°C | C |

Table 6: Thermal storage parameter

| Thermal storage parameter | Type | Values | Units |
|---------------------------|------|--------|-------|
| HTF | Hitec solar salt | - | - |
| Tank height | - | 15 | - |
| Parallel tank pairs | - | 2 | - |
| Cold tank heater set point | - | 260°C | C |
| Hot tank heater set point | - | 525°C | C |

Table 7: Result of parabolic trough simulated by system advisor model

| Metric | Values |
|--------|--------|
| Annual energy (Year 1) | 240, 646, 912, kWh |
| Gross-to-net conversion | 79.3% |
| Capacity factor (Year 1) | 18.3% |
| Annual water usage | 42,227 m³ |
| PPA price (Year 1) | 16.75 c kWh⁻¹ |
| Levelized PPA price (Nominal) | 25.16 c kWh⁻¹ |
| Levelized PPA price (Real) | 20.04 c kWh⁻¹ |
| Levelized COE (Nominal) | 22.48 c kWh⁻¹ |
| Levelized PPA COE (Real) | 17.90 c kWh⁻¹ |
| Investor IRR | 14.99% |
| Year investor IRR achieved | 6 |
| Investor IRR at end of project | 15.22% |
| Net capital cost | [535, 602, 144] |

After putting the values of the different parameter in system advisor model SAM we get the following result which shows that CSP is best option to use in hybridization for Pakistan to tackle the energy crises. Table 7 overall efficiency and Table 8 and Fig. 9 show monthly wise generation of electricity in kWh.

The results we obtained from simulation show that parabolic trough is good for a generation of electricity when we use Hitec on a place of molten salt use as heat transfer fluid in receiver tube. Because Hitec HTF is less minimum start-up the temperature and high maximum temperature which increase cycle conversion efficiency then molten salt. Many researchers use molten salt as HTF in a parabolic trough which is not better than Hitec. The cycle conversion efficiency of molten salt is 59% while conversion efficiency of Hitec is 74%. Figure 8, we show annual energy production when using Hitec HTF and Fig. 9 show annual energy production when we using Molten salt HTF. And gradually, decrease show that the
Fig. 10: Annual energy production using molten salt heat transfer fluid

efficiency of plant decreases per year because of system losses and many other losses. From the Fig. 9 and 10, we conclude that Hitec HTF is better than molten salt HTF because of electricity generation from Hitec HTF is $2.4\times10^8$ kWh and generation from MS HTF is $2\times10^8$ kWh. While cost of both of technology is same.

CONCLUSION

To generate electricity efficiently by using CSP, recognize an exact path for Pakistan in terms of CSP energy utilization hybrid system that will individually provide a constant power source from biogas and CSP. The DNI of Quetta is high, i.e., 2301 kW m$^{-2}$ and in Karachi is 1576 kW m$^{-2}$. But Government of Pakistan (GOP) estimates that 71,000 tons of solid waste is produced per day, commonly from major resident areas. Karachi Pakistan’s main city produces more than 9,000 tons of municipal waste daily and Quetta has generated only 326 tons of municipal waste. So, select Karachi as a replacement for of Quetta because of modeling of hybridization both renewable resources is necessary. For this purpose, the efficiency of PT by using Hitec heat transfer fluid can be improved instead of using molten salt because Hitec HTF has high conversion efficiency than molten salt. Molten salt HTF is a good option in cases of the technology of high output temperature where the minimum temperature for operation is high, i.e., 232 Co whereas Hitec HTF is better for PT because minimum temperature required for operation is low, i.e., 142 Co.

RECOMMENDATIONS

The future plan is given below:

- To work on HTF to reduce the minimum initial temperature required for operation
- To work on HTF to increase the maximum temperature required for set-up as this HTF will not only increase the cycle conversion efficiency of the system (which will finally, lead to the intensification of electricity generation) but will upgrade conversion efficiency
- To work on storage of this energy to make it productive for the prolonged period of time

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