# Replacing Fossil Fuel based thermal generation with Renewable Fuel in textile and garments sector in Pakistan

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für Internationale
Zusammenarbeit (GIZ) GmbH

# Introduction

# Objectives

The goal of the study is to identify potentials to reduce the GHG emissions with the focus on renewable energy resources in Pakistan textile and garments sector

**Phase-1:** Pre-feasibility study on renewable fuel market and identify alternative renewable sources for boilers or thermal application replacing fossil fuel

**Phase-2:** To conduct a detail study on the most relevant and suitable renewable fuel source to use in boiler operation in the industry (proposed in Way Forward)

**Phase-3:** To support H&M to initiate a pilot in 8 - 10 factories and demonstrate the viability of renewable fuel boiler

# AREAS OF THERMAL ENERGY DEMAND IN TEXTILE AND GARMENT FACTORIES

| Woven & Knitted Fabric Processing (Non-denim) | Water | Steam |
|---|---|---|
| Fabric Bleaching | Yes | Yes |
| Fabric Washing | Yes | Yes |
| Fabric Dyeing and Printing (Reactive) | Yes | Yes |
| Fabric Finishing | Yes | Yes |

| Denim Fabric Processing | Water | Steam |
|---|---|---|
| Denim Rope Dyeing | Yes | Yes |
| Denim Fabric Processing | Yes | Yes |
| Denim Fabric Finishing (Sizing, Mercerizing etc.) | Yes | Yes |

| Denim Garment Process | Water | Steam |
|---|---|---|
| Denim Garment Dyeing | Yes | Yes |
| Garment Washing | Yes | Yes |
| Laundry Drying | No | Yes |
| Garment finishing | Yes | Yes |

| Knitted Garment Process | Water | Steam |
|---|---|---|
| Garment finishing (pressing) | No | Yes |

# Renewable Energy Options Evaluated

## Bio Mass

Steam generation (Combustion and Gasification)

## Solar Energy

Mainly Solar Thermal and comparison with Solar PV

# Bio-mass for Steam generation

# Bio-mass availability from various sources in Pakistan

| Bio-mass | Bio-mass available for energy generation<br><br>(Million Tonne/year) | Energy generation potential<br><br>(GWhth/year) |
|---|---|---|
| Bagasse | Negligible | 0.00 |
| Sugar Cane Trash | 2.0 | 555.55 |
| Rice Straw | 2.23 | 619.44 |
| Rice Husk | 0.44 | 122.22 |
| Wheat Straw | Not Considered | 0.00 |
| Cotton Stalk | 2.67 | 741.66 |
| Maize Cob | 0.26 | 72.22 |
| Maize Husk | 0.173 | 48.05 |
| Maize Stalk | 0.985 | 273.61 |
| **Sub-total** | **8.758** | **2,432.77**<br><br>**Eq. to 73 MW Power or 361 TPH steam)** |

Estimated using updated crop data and Residue to Crop Ratio identified by World Bank Report in 2016.

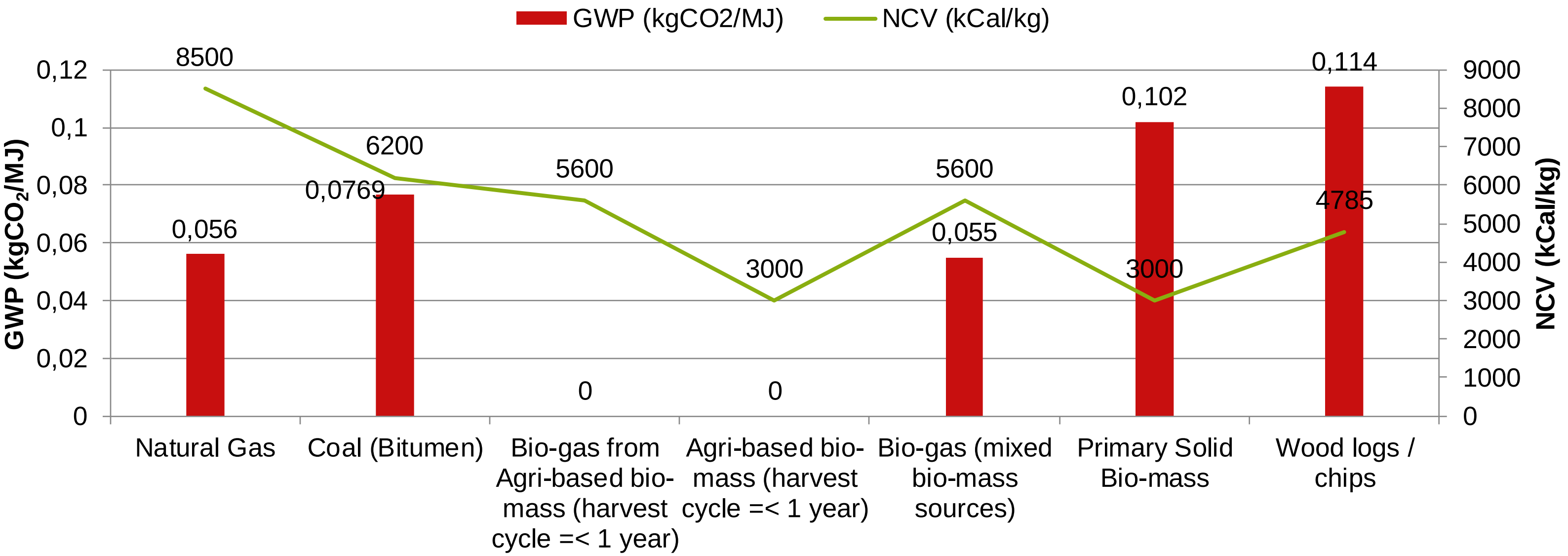
# Bio-mass Fuel Prices in Pakistan

Bio-mass prices are variable; farther a factory is located from bio-mass source, more is the price

| Bio-mass | Price |
|---|---|
| **Rice Husk** | 5.5-8.0 USD-cents/kg (9-13 PKR/kg) |
| **Maize Cob** | 5.5-8.0 USD-cents/kg (9-13 PKR/kg) |
| **Other bio-mass** | No reliable price data available |

# Global Warming Potential and Calorific Values of Available Fuels for Boilers

- Agriculture based bio-mass is considered to have Net-Zero Emissions as per IPCC 2019 guidelines
- General NCV of agri-based bio-mass is quite low compared to Natural Gas and other alternatives
- Bio-gas contains higher NCV but becomes even more expensive, and requires larger scales



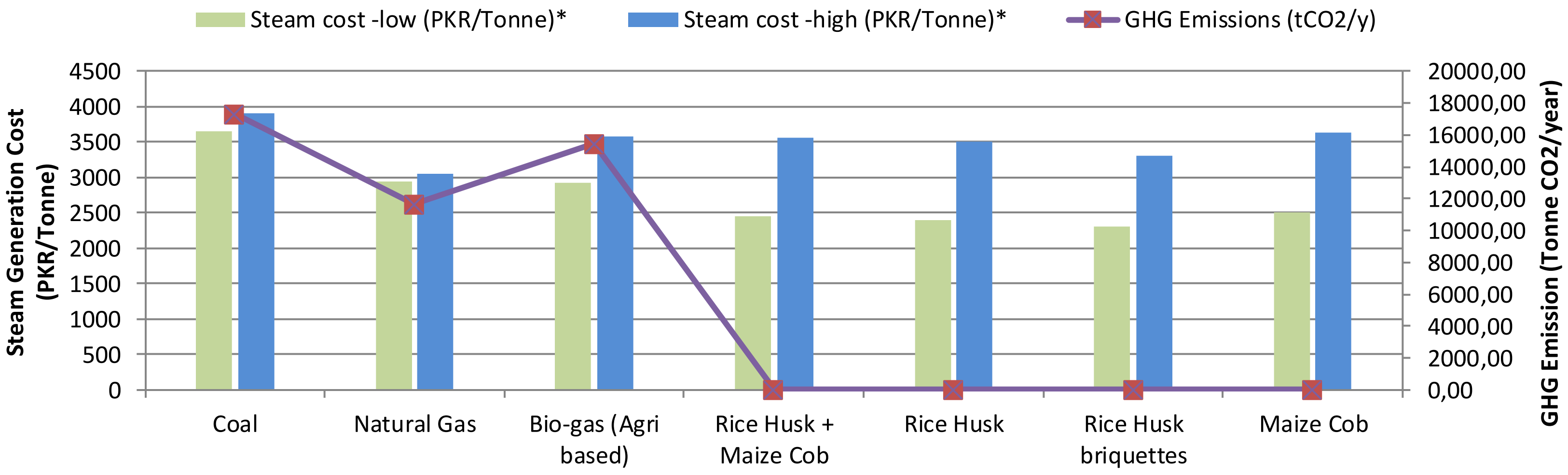
# Technology options for steam boilers (considering 10TPH boiler for comparison)

| Fuel | Boiler Technology | Investment (USD) | Investment for emission control equipment (USD) | Additional Space required |
|---|---|---|---|---|
| **Natural Gas** | Fire tube | 220,000 | - | - |
| **Rice Husk** | Water tube Travelling Grate, Circulating Fluidized Bed | 320,000 – 400,000 | 18,000 – 40,000 | 7,700 $m^3$ |
| **Rice Husk briquettes** | Water tube Travelling Grate | Boiler 320,000 – 400,000<br>Briquetting machine ~5,000 | 18,000 – 40,000 | 9,000 $m^3$ |
| **Wood Logs / chips / saw dust** | Water tube Travelling Grate | 320,000 – 400,000 | 18,000 – 40,000 | 7,700 $m^3$ |
| **Wood chip/saw dust briquettes** | Water tube Travelling Grate | Boiler 320,000 – 400,000<br>Briquetting machine ~5,000 | 18,000 – 40,000 | 9,000 $m^3$ for storage |
| **Bio-gas (Agri-based or sewage waste bio-mass)** | Bio-gasification + fire tube boiler | 860,000 – 1,100,000 | - | 7,700 $m^3$ for storage<br>1,676 $m^3$ for gasifier |

***Note: Investment for natural gas boiler is not mentioned considering these are already installed in the factories and are to be replaced with other presented options.***

# Comparison of Steam Cost and Annual GHG Emissions in Pakistan
**(considering 10TPH boiler for comparison)**

- Lowest steam generation cost on Natural Gas with least variations among regions; but price inflation and supply fluctuation are high
- Coal prices have recently jumped to all time high; making factories shift from coal to natural gas
- Bio fuels are subject to more variable steam cost due to more frequent price fluctuations. Availability of bio-mass is a big challenge.



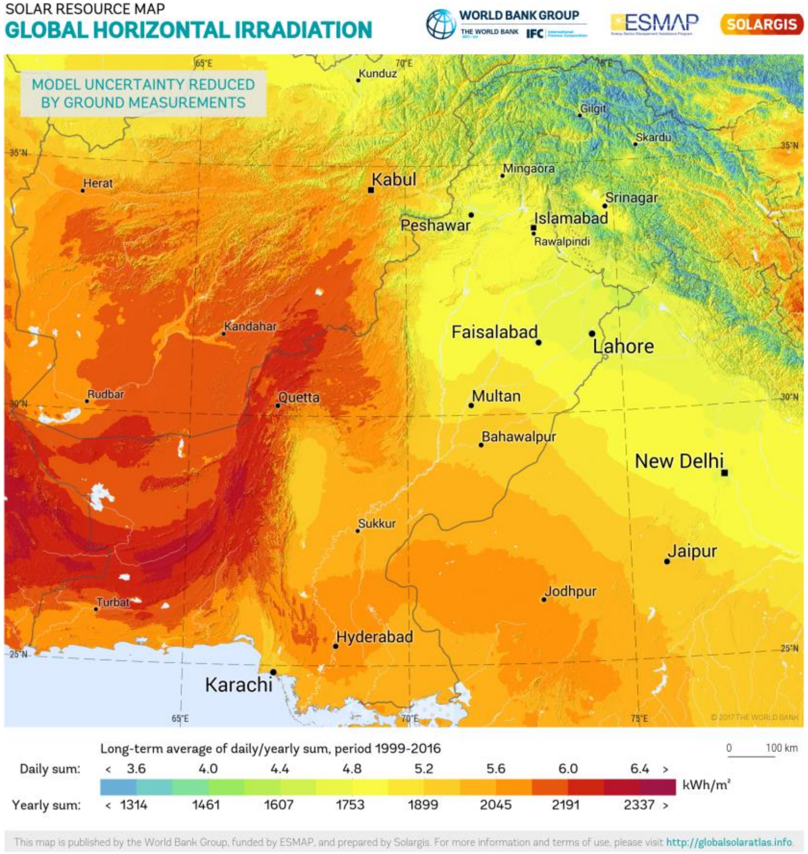
# Limitations of Bio-mass based Steam Generation Systems

- Natural gas combustion efficiency is easier to control compared to solid fuels like bio-mass
- Bio-mass fuels require extensive monitoring and manual control by operators; automation works only if bio-mass type is fixed and quality is consistent
- Not all boilers are capable of firing all types of bio-mass materials.
- Moisture in bio-mass varies across the year which significantly effects boiler combustion efficiency
- Large storage space is required to stock enough bio-mass to allow natural moisture reduction as well as to reduce transportation cost
- Bio-mass price fluctuations result in significant variation in steam generation cost which puts the bio-mass behind natural gas in the race.
- Managing the supply chain for bio-mass is a formidable challenge because of the distributed nature of the resources, availability over a short period of harvesting time and its physical characteristics.
- Bio-mass combustion generates significant amount of ash and particulate matter for which special arrangements are required for
  - filtering out the ash from air and water
  - drying, handling and storing the ash
  - safe disposal. All these arrangements result in additional operational cost

# Solar Energy

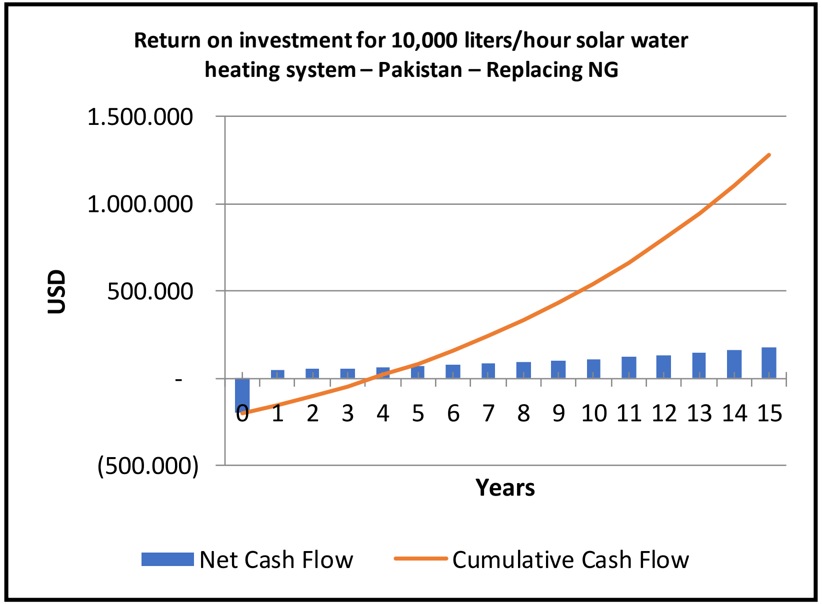
# Global Horizontal irradiation in Pakistan

- Potential Global Horizontal Irradiation (GHI) in Pakistan varies from 3.6 to 6.4 kWh/m2
- Great potential for Solar Water Heaters



# Economic feasibility of Solar Water Heating – Pakistan
## Replacing Natural Gas Heat

- Analysis is conducted considering hot water demand of 10,000 litres per hour, heating water from 25°C to 65°C on average (may go up to 90°C in summer) for 8 hours a day.

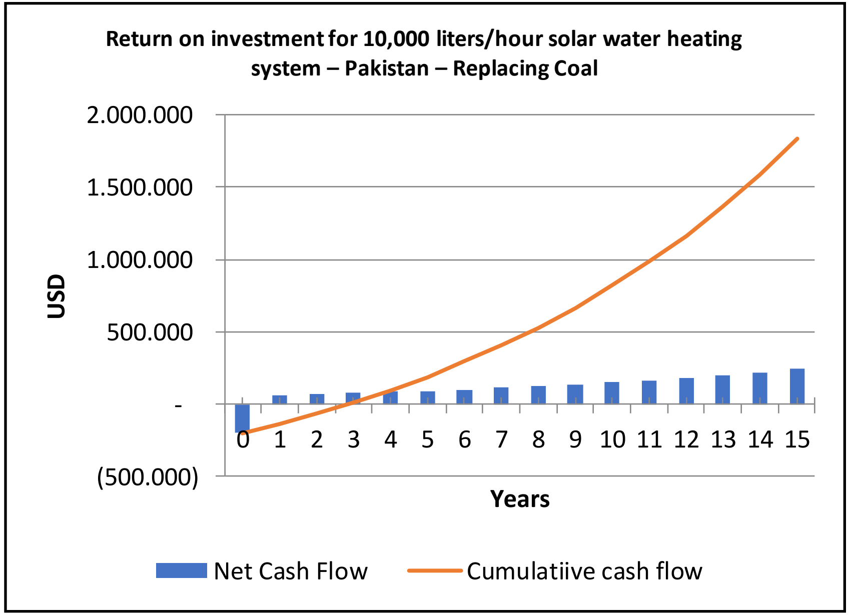



| | | |
|---|---|---|
| **Water flow** | **80** | **$m^3/d$** |
| **Collectors (50 tubes each)** | 180 | |
| **Average Temperature gain (ΔT)** | 40 | C |
| **Energy gain** | 13,408 | MJ/d |
| **Hours of operation (average)** | 8 | hrs |
| **Footprint area** | 1,487 | m2 |
| **Specific weight of the system** | 38.75 | $kg/m^2$ |
| **Gross weight of the system on rooftop** | 57,606 | kg |
| **Storage tank** | 20 | $m^3$ |
| **Pumping energy cost** | **3,409** | USD/year |
| **Natural Gas saving** | 711 | $m^3/d$ |
| **GHG emission reduction** | **434** | $tCO_2$/year |
| **Natural Gas cost saving (1st year)** | **46,628** | USD/year |
| **Investment** | 200,237 | USD |
| **Dynamic payback period** | **4** | years |
| **Lifecycle** | 15 | years |
| **IRR** | **32** | % |
| **NPV** | **396,005** | USD |

# Economic feasibility of Solar Water Heating – Pakistan

## Replacing Coal Heat

- Similar Analysis for Pakistan considering that solar water heater replaces steam generated by coal.




| | | |
|---|---|---|
| Water flow | 80 | $m^3/d$ |
| Collectors (50 tubes each) | 180 | |
| Average Temperature gain ($\Delta T$) | 40 | C |
| Energy gain | 13,408 | MJ/d |
| Hours of operation (average) | 8 | hrs |
| Footprint area | 1,487 | m2 |
| Specific weight of the system | 38.75 | $kg/m^2$ |
| Gross weight of the system on rooftop | 57,606 | kg |
| Storage tank | 20 | $m^3$ |
| Pumping energy cost | **3,409** | USD/year |
| Coal saving | 1.1 | Tonne/d |
| GHG emission reduction | **862** | $tCO_2$/year |
| Coal cost saving (1st year) | **67,346** | USD/year |
| Investment | 200,237 | USD |
| Dynamic payback period | **3** | years |
| Lifecycle | 15 | years |
| IRR | **41** | % |
| NPV | **610,566** | USD |

# Economic feasibility of Solar PV - Pakistan

- Analysis is conducted considering same footprint area as for Solar Water Heater
- IRR is lower when replacing Natural gas based power due to low price of natural gas
- GHG emission reduction potential for both options is equivalent

| | Solar PV replacing Grid Power | Solar PV replacing Natural Gas Power | Units |
|---|---|---|---|
| **Footprint area** | 1,487 | | $m^2$ |
| **Typical potential (monocrystalline)** | 7.3 | | $m^2/kW$ |
| **Total potential capacity** | 203 | | kW DC |
| **Annual energy generation capacity** | **242,190** | | kWh/Year |
| **Energy gain** | **2,389** | | MJ/d |
| **GHG emission reduction** | **106** | **137.4** | tCO2/year |
| **Hours of operation (average)** | **3.8-4.5** | | hrs |
| **Specific weight of the system** | 25 | | $kg/m^2$ |
| **Gross weight of the system on rooftop** | 37,175 | | kg |
| **Investment** | 144,142 | | USD |
| **Electricity cost saving (1st year)** | **22,152** | **16,245** | USD/year |
| **Dynamic payback period** | **7** | 9 | years |
| **Lifecycle** | 20 | | years |
| **IRR** | **20.3** | **14.5** | % |
| **NPV** | **161,212** | **63,574** | USD |



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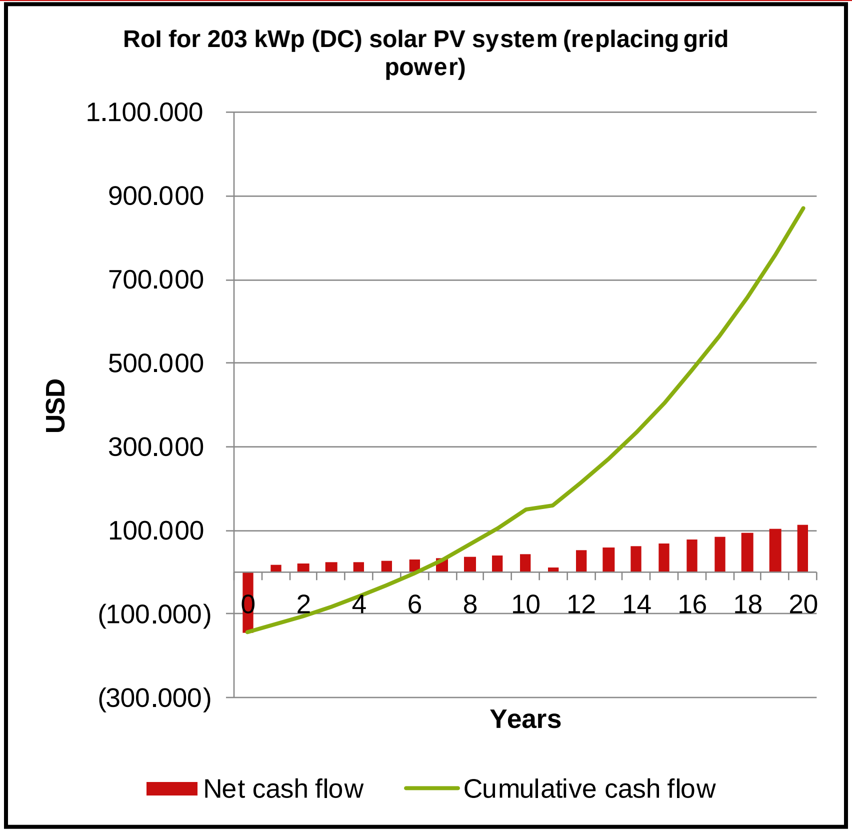
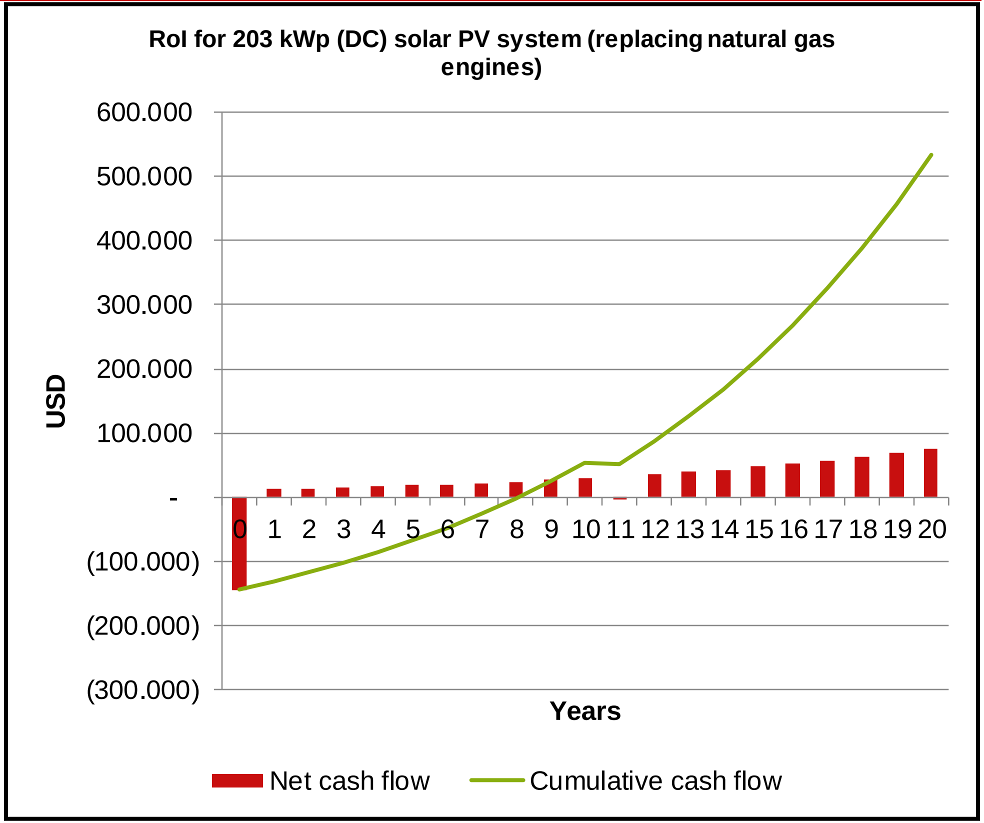
# Economic feasibility of Solar PV - Pakistan

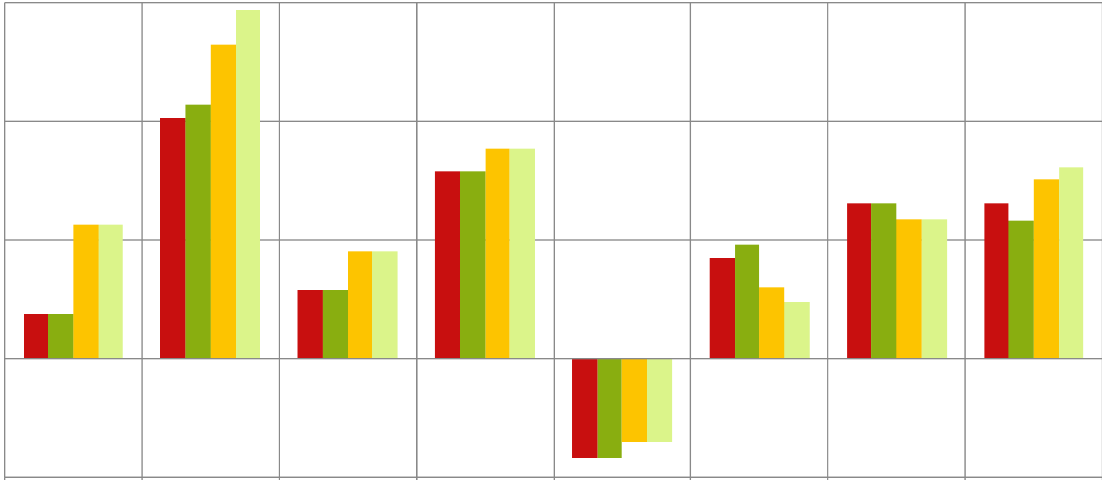


# Comparison between Solar Water Heater and Solar PV

- Higher energy gain by Solar Water Heater
- Potential to reduce GHG emissions is much higher for Solar Water Heater compared to Solar PV.
- Almost equivalent IRR for Solar PV replacing grid power and Solar Water Heater. Very low IRR for Solar PV replacing Natural Gas based power
- Solar PV system are easier to install and operate as they do not require allied utilities like pumps, heat exchangers and storage tanks.
- Specific weight of Solar PV is lesser than that of solar water heaters reducing requirements for structural reinforcement.
- Solar water heaters have shorter lifecycle compared to Solar PV and also have higher operations and maintenance costs.

# Comparison between Solar Water Heater and Solar PV - Pakistan



| | Energy gain (GJ/d) | GHG emission reduction (tCO2/y) | Hours of operation (hrs/d) | Gross weight (Tonne) | Investment (M-USD) | Dynamic payback (y) | Lifecycle (y) | IRR % |
|---|---|---|---|---|---|---|---|---|
| Solar PV (Replacing Grid) | 2,38 | 106 | 3,80 | 37,18 | 0,14 | 7 | 20 | 20 |
| Solar PV (replacing NG Power) | 2,38 | 137 | 3,80 | 37,18 | 0,14 | 9 | 20 | 15 |
| Solar Water Heater (replacing NG) | 13,41 | 434 | 8,00 | 57,61 | 0,20 | 4 | 15 | 32 |
| Solar Water Heater (replacing Coal) | 13,41 | 862 | 8,00 | 57,61 | 0,20 | 3 | 15 | 41 |

# Conclusion for Bio-Mass

- In Pakistan, Bio-mass competes well in this aspect with coal and natural gas. However, there are no GHG emissions associated with Agri-based bio-mass fuels, hence establishing these as more suitable in terms of climate improvement targets.
- Bio-mass fuel supply chain management is a major concern which results in multiple challenges, especially, price fluctuation and sufficient availability.
- Another important element to consider for switching to bio-mass fuels is additional space and human resource requirement which may become a challenge for smaller companies having low steam demand; however, medium and large-scale companies usually have sufficient resource available.
- Investment required for switching to bio-mass fuels may become a relevant indicator as well for companies who do not have a bio-mass boiler available at site. It is observed that larger companies keep bio-mass fired boilers as back-up option; in which case the critical indicators would be supply, steam cost and GHG emissions.
- It is evident that there might not be enough bio-mass available to drive a major shift from fossil fuels to bio-mass for energy generation in Pakistan.

# Conclusion for Solar Energy

- Solar Water heaters carry significant potential for thermal energy generation and GHG emission reduction.
- Requirement of hot water in garment washing process is usually intermittent. However, careful planning and proper designing and insulation of water circuit may resolve this issue to some extent.
- Industrial scale Solar Water Heaters may not be feasible for factories using steam only for garment pressing
- Solar water heaters are highly suitable for factories having more stable hot water demand, such as fabric processing mills and large garment washing units.
- Detailed feasibility study may be conducted on Solar Water Heaters for a specific case so that detailed analysis of hot water demand and generation potential could be conducted.
- Solar Photo Voltaic may also be considered for reducing dependence on national grid or fossil fuel (natural gas) fired engines.
- Solar PV systems require much more investment for same amount of energy compared to solar water heaters. However, it presents considerably less challenges.
- GHG emission reduction for solar PV is considerable when replacing grid power, however, potential significantly reduces when replacing natural gas power.

# Mapping biomass /biofuel /alternate resource (Solar) potential assessment

| Renewable energy options | Energy cost | GHG emission | Nature and direction of regulation | Geography | Seasonality | Key vendors | Pricing considerations | Current Uses |
|---|---|---|---|---|---|---|---|---|
| **Bio-mass** | Comparable steam cost compared to natural gas and coal | No GHG emission accounted for agri-based bio-mass with harvest cycle equal or less than 1 year | No restriction | Geographical variation in supply | Fluctuating based on crop harvesting cycle | No formal data of bio-mass suppliers; technology suppliers available but not formally organized | Basic price data available; concrete fluctuation data not available | Estimates made for 2019-20 for Pakistan based on data of 2015. |
| **Solar Thermal** | Financially feasible | Significant reduction | State Bank of Pakistan Financing Scheme for Renewable Energy 2016 | Geographically variable irradiation potential | Seasonally variable irradiation potential | Limited suppliers for industrial solutions, not formally organized | Generally established prices but variable based on currency exchange rate | No mapping available for industrial sector |
| **Solar PV** | Financially feasible compared to grid; longer payback against natural gas based power | Significant reduction | State Bank of Pakistan Financing Scheme for Renewable Energy 2016 | Geographically variable irradiation potential | Seasonally variable irradiation potential | Multiple vendors in Pakistan. | Generally established prices but variable based on currency exchange rate | No mapping available for industrial sector |



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# Way Forward

**Option-1:** Develop pilot for adopting bio-mass for one selected supplier

ideally selecting a supplier where bio-mass boilers are already installed or are located near the Agri-based bio-mass source

- Improving efficiency of the bio-mass steam generation system (Training, Briquetting, Combustion efficiency, heat recovery etc.)
- Adopting new bio-mass boiler using bio-mass from reliable source of Agri-based bio-mass
- Selecting right steam source mix to achieve GHG reduction while maintaining steam cost in acceptable range

**Option-2:** Develop pilot for adopting solar energy (thermal or PV) for one selected supplier

- Assessing solar energy potential at site
- Selecting suitable solar energy option (thermal, PV or both)
- Conducting pre-feasibility for selected option along with financial analysis and suitable financing options

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