Abstract—As the wheel of modernization moves, it is usually accompanied by fuel demand, mainly powering our industry. In Jubail industrial city this is true as well as the petrochemical industry is seen as an opportunity and challenge. In Jubail Industrial College (JIC), as an educational organization, we decided to be part of the sustainable solution as we are located in Jubail Industrial City and we believe that it’s our moral responsibility to participate in the change and teach it to the future generation. JIC Green Initiative is our model which integrates solar energy, solid waste recycle, food waste recycle, wind energy, bio-gas and electric vehicles to come up with an example which could be measured and achieved, including all economic benefits, payback period and reduction in carbon foot print in JIC.

Index Terms—Green campus, electric vehicles, bio-gas, wind energy.

I. INTRODUCTION

In Jubail Industrial College we decided to give a model that every industrial city can follow, so beside the petrochemical pollution from the industrial city we are living in our project will be green eraser to reduce the pollution in our environment.

The project is integrated projects like recycling, Green power generation, implementing EV, education of renewable energy and increase of green landscape see Fig. 1. Green energy include solar panels, wind turbine and bio-gas see Fig. 2.

To ascertain that JIC green initiative project is credible and applicable, it is required to define the economic benefits of the project, find out the payback period and amount of carbon dioxide (CO₂) that can be saved in the environment.

As shown in Fig. 1 above, the JIC Green Initiative Project consists of six segments:
1) Increase Green landscaping
2) Carbon foot print analysis
3) Zero-car emission campus
4) Renewable energy centre
5) Recycling
6) Green Power Generation

In addition, green power generation consists of six segments: ‘see Fig. 2.’
1) PV- Green Car Park
2) Solar Energy water heater
3) Biogas Plant
4) Wind Turbine
5) PV street lights
6) College buildings PV

II. ELECTRIC VEHICLE (EV)

Electric Vehicle in JIC will result in saving carbon footprint as well as save fuel, taking in consideration current four thousand (4000) cars in JIC campus; new English Language institute’s full capacity is about six thousand (6000) students meaning another 6000 cars, therefore a total of ten thousand (10,000) cars.

Fuel of 10,000 cars will be saved by utilizing the following:
1) Electric bus shuttle
2) Bicycle
3) Shaded walk ways with solar panel collectors
4) Locations that are currently car park will be converted into green Landscaping
5) Tunnel connection between the external car park and the college for safe movement across the road (target future Green Photo Voltaic Car Parking).

With the use of electric vehicle to commute staff and students inside JIC, the expected saving in terms of liters of...
fuel:
- Assuming, on an average, 10% of fuel tank will be consumed for transportation inside JIC for whole day.
- Then 10% multiplied by 5 working days in one week, 50% of your car fuel tank will be saved in one week.
- For four weeks a month, 200% of fuel tank will be saved or two times filling of your car.
- Taking 2.5 Litre Camry as a model.
- If we consider an average size car Camry 4-cylinder
- 28 MPG Combined city/hwy
- 25 city
- 35 highways
- 17 gallon fuel tank
- Price of 1 gallon of fuel in Saudi Arabia = 0.544 US$
- A full tank will cost = 16.49 US$
- Therefore monthly saving will be 16.49 * 2 = 32.98 US$
- For one car saving will be 32.98 * 12 months = 395.76 US $ annual
- For ten thousand cars the saving will be:
  - 395.76 * 10,000 ≈ 4 million US dollar annually

Knowing that the cost of the EV system planed for JIC will be ≈ 523,000 US Dollar. ‘See Table I.’

| Sr. | Items/PS. | Description                | Cost (SAR) |
|-----|-----------|-----------------------------|------------|
| 1   | 8         | Golf cars                   | 150,000    |
| 2   | 10        | E.V. Chargers for green park| 37,775     |
| 3   | 12        | External parking’s E.V. chargers Shuttle bus | 98,775     |
| 4   | 20        | 14 passenger Shuttle bus    | 843,750    |
| 5   | 10        | 14 passenger Shutle bus     | 421,874    |
| 6   | 1         | Car port with EV Charger    | 247,500    |
| 7   | 2         | EV maintenance truck        | 84,750     |
| 8   | 100       | Bicycle for students        | 75,000     |

Total Cost: KSA 1,959,424

Therefore if we assumed that we initially owned those cars (gasoline) which will cost us to move using them inside the campus 4 million dollar then the paybacks period will be 1.6 months!

Moreover, the saving in CO₂ = 3.6 Tone. [1]

For 10,000 cars, we will be saving the environment an amount of CO₂ equivalent to

3.6 Tone * 10 000 = 36 000 Tone of CO₂.

III. STREET PHOTOVOLTAIC (PV) LIGHTS

A. Conventional PV Street Lights

As a very essential part of the whole project; STREET LIGHTS in Jubail Industrial College.

The target is to replace the traditional way of lighting using FOSSIL FUEL by one of the most efficient; green and healthy which is SOLAR way as shown in Fig. 3.

As shown in Table II. It highlights after surveying; different Types of Lights, Wattage, Quantity and Cost as per Conventional Solar Street Lights.

The following figures and results must be highly considered:

- The Total Cost of lights is 259776 US$ which means about 1M SAR
- The Total Power is 88.404 kW
- The Annual Total Energy is 88.404 * 8 * 366 = 258846.91 kWh
- The Annual Total Billing is 258846.91 * 32 (Educational Facilities” 32 Halalah/kWh”) = 8283101.12 SAR =22088.27 US$

It is clear that the payback period will be about 12 years.

It is essential to know how much CO₂ emissions prevented:

The CO₂ Emission Factor used is 0.527 kg / kWh

So, 258846.91 kWh * 0.527 = 136412.3 kg

B. Led Solar Street Lights:

With the development of the Conventional (PV) Street Lights, Led (PV) Street Lights became preferable to be used nowadays as shown in Fig. 4.

Table III shows a comparison between Led Lights and Conventional Lights powered by (PV) in terms of wattages.

As shown in Table IV. It highlights after surveying; different Types of Lights, Wattage, Quantity and Cost as per Led (PV) Street Lights.

The following Figures and Results must be highly considered:

- The Total Cost of lights is 41865 US$ *3.7506 which means about 157019 SAR
- The Total Power is 48.360 kW

Fig. 3. Conventional solar street light.

Fig. 4. Led solar street lights.
### TABLE II: DIFFERENT LIGHTS IN JIC CAMPUS

| S. No. | Type of Conventional Lights | Wattage (W) | Quantity | Total Wattage (W) | Price/Unit (USD) | Total Price (USD) |
|--------|----------------------------|-------------|----------|------------------|-----------------|------------------|
| 1      | Street Lights (1*400W)     | 400         | 125      | 50000            | 1019            | 127375           |
| 2      | Global Lights (4*100W)     | 100         | 4        | 1600             | 1019            | 4076             |
| 3      | Global Lights (4*15W)      | 15          | 50       | 8750             | 175             | 157019           |
| 4      | Global Lights (1*15W)      | 15          | 111      | 1665             | 85              | 9435             |
| 5      | Pathway Lights (1*80W)     | 80          | 52       | 4160             | 230             | 11960            |
| 6      | Pathway Lights (1*125W)    | 125         | 111      | 13875            | 350             | 38850            |
| 7      | Bollard Lights (1*26W)     | 26          | 24       | 624              | 85              | 2040             |
| 8      | Parking Shed Lights (1*40W)| 40          | 337      | 13480            | 170             | 57290            |
| Total  | -                          | -           | -        | 88404 (W)        | -               | 259776 (USD)     |

### TABLE IV: STATISTICS OF ALL TYPES OF LIGHTS AND COSTS IN JIC CAMPUS WITH LED

| S. No. | Type of Led Lights | Wattage (Led Lamps) (W) | Quantity | Total Wattage (W) | Price/Unit (USD) | Total Price (USD) |
|--------|-------------------|--------------------------|----------|------------------|-----------------|------------------|
| 1      | Street Lights     | (1*400W)                 | 400      | 50000            | 52              | 6500             |
| 2      | Global Lights     | (4*100W)                 | 400      | 1600             | 145             | 580              |
| 3      | Global Lights     | (4*15W)                  | 400      | 600              | 80              | 4800             |
| 4      | Global Lights     | (1*15W)                  | 100      | 1110             | 133             | 14763            |
| 5      | Pathway Lights    | (1*80W)                  | 400      | 2080             | 40              | 2080             |
| 6      | Pathway Lights    | (1*125W)                 | 400      | 4440             | 30              | 3330             |
| 7      | Bollard Lights    | (1*26W)                  | 200      | 360              | 49              | 1176             |
| 8      | Parking Shed Lights | (1*40W)              | 150      | 20220            | 28              | 9436             |
| Total  | -                 | -                        | -        | 48360 (W)        | -               | 41865 (US$)      |

### TABLE III: COMPARISON BETWEEN LED AND CONVENTIONAL LAMPS

| Led Lamps W | 3W | 5W/7W | 13W | 40W | 200W | Conventional Lamps W |
|-------------|----|-------|-----|-----|------|----------------------|
| Total Cost (US$) | 259776 | 41865 | 88.404 | 48.360 | 157019 (SAR) |
| Total Power (Kw)  | 88.404  | 48.360 | 141598 | 12081 | 74622.15 |
| Annual Total Energy (kWh) | 258846.91 | 141598 | 161500 | 74622.15 |
| Annual Total Billing (US$) | 22088.27 | 12081 | 22088.27 | 12081 |
| CO2 Emission         | 136412.3 | 74622.15 |

### TABLE V: EFFICIENT LED LIGHTS

| In Terms Of   | Conventional Lights | Led Lights |
|---------------|---------------------|------------|
| Total Cost (US$) | 259776 | 41865 |
| Total Power (Kw)  | 88.404  | 48.360 |
| Annual Total Energy (kWh) | 258846.91 | 141598 |
| Annual Total Billing (US$) | 22088.27 | 12081 |
| CO2 Emission         | 136412.3 | 74622.15 |

The Annual Total Energy is 48.360 * 8 * 366 = 141598 kWh

The Annual Total Billing is 141598 * 32 (Educational Facilities’ 32 Halalah/kWh”) [KSA currency]

= 4531136 H = 45311.36 SAR =12081 US$

It is clear that the payback period will be about 7 years.

It is essential to know how much CO2 emissions will be prevented:

The CO2 Emission Factor used is 0.527 kg / kWh, So, 141598 kWh * 0.527 = 74622.15 kg

Conclusion related to PV street lights:

Although the (PV) power is already used with the two types of Lights, it is very clear that using the Led Lights is much more efficient than the Conventional Lights as shown in Table V.

Fig. 5 illustrates the eight types of Led Lights that were chosen to replace the Conventional Lights in the project.

![Fig. 5. LED substituted the conventional lights.](image)

**IV. GREEN PHOTOVOLTAIC CAR PARK (GPCP)**

A main part of the project is to add a shade to a huge car parking and to provide it with solar panels. The two options are usually for photovoltaic system either on grid system or off grid system. For the large area propose 161500 m² on grid system is the only feasible option as it is almost impossible to...
come up with a battery bank that can serve this large area and also the cost will be high and the maintenance very costly.

The bad news is the on grid power is not yet offered in Saudi Arabia for public use but as the project belong to a governmental segment (college) a special permission can be tried, therefore we are assuming here an on grid power system.

For the use of the parking ‘see Fig. 6.’ which is shading of the car area plus the streets.

Table VI below shows the production, environmental impact, cost and payback period see Table VII. Please note that the following calculations are based on estimated areas, results are adopted from various internet sites regarding productivity, environmental impact, and costs, numbers are sometimes rounded.

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**Table VI: Power Produced by Solar Panels**

| Manufacturer   | Work area (m²) | Solar panel area | Panel power | MW(DC) | MW(AC) | MWh Annual | Tons of CO₂ |
|----------------|----------------|------------------|-------------|--------|--------|------------|-------------|
| (1) Anern china| 161477         | 1.64             | 250 w       | 24.5   | 19.6   | 28616      | 17341       |
| (2) Namkoo china| 161477         | 1.2              | 260 w       | 35     | 28     | 40880      | 24773       |

**Table VII: Cost of Green (PV) Car Park**

| Manufacturer | Electricity Cost in SAR | Electricity Cost in US ($) | Total constructing cost SAR ($) | Payback period (Years) |
|--------------|-------------------------|-----------------------------|--------------------------------|------------------------|
| a. Anern     | 9.15 M                  | 2.4 M                       | 80 M (21.35 M)                 | 9                      |
| b. Namkoo    | 13.1 M                  | 3.5 M                       | 92 M (24.5 M)                  | 7                      |

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Area of parking = 161477 m²,
1) Anern manufacturer [2] has 1.64176 m² photovoltaic panel of 250 w power provided by Nearn Industry Group Limited (China);

Area of 250 watt photovoltaic panel = 1.64176 m²
Number of solar panels = 161477 / 1.64176 = 98356 panel
DC power = 98356 * 250 w = 24589000 w = 24.5 MW
AC power = DC power * 0.8 = 19.6 MW

Although sun hours reach up to 8.4 hours in Saudi Arabia eastern province every day but 4 hours is the sun peak hours in Jubail Industrial City then,

Annual AC MWh power generated = 19.6 MW * 365 day in a year * 4 hours peak sun in Jubail city = 28616 MWh
About 17000 tons of CO₂ will the saving of Green PV Car Park [3].

Cost as per kWatt in Saudi Arabia for Governmental Buildings is 0.32 SAR.

Cost of generated electricity = 40880000 * 0.32 = 13.1 M SAR = 3.5 M us$.

- Construction cost of solar system of Anern manufacturer according to Anern Industry Group Limited [2] China 871060 $ as per 1Mw on-grid Solar Power, therefore to the construction cost for 24.5 MW DC = 24.5 * 871060 $= 21340970 $ = 21.35 M $, Payback period = total construction cost/ cost of power annually = 21.35/2.4 = 8.9 years ≈ 9 years see Table VII

- Construction cost of solar system of Namkoo china [4] 700000 $ = as per 1Mw 1Mw on-grid Solar Power, therefore to the construction cost for 35 MW DC = 35 * 700000 $= 24500000 $ = 24.5 M $, Payback period = total construction cost/ cost of power annually = 24.5/3.5 = 7 years see Table VII

Using carbon footprint carbonfund.org calculator [3], will be 17341 ton of CO₂ is the saving of pollution when using Anern product and 24773 ton of CO₂ is the saving of pollution when using the Namkoo product.

Finally nine years is the payback period for Anern panel whereas seven years is the payback period for Namkoo solar panel see Table VII.

As a result Namkoo system is more suitable as it offer higher efficiency as well as better payback period.

Total parking cost about 13 million US$ and total power produced is about 40880 MWH annually this power will produce what is equivalent to 3.5 million US$ annually. The produced power represents 97.3% of the annual Jubail Industrial College, which is 42000 MWH.
V. SOLAR HEATER

Water heating accounts for about 30 percent of an average household’s total greenhouse gas emissions and about the same proportion of total energy use [6]. At Jubail Industrial College (JIC) Campus, water heating by conventional methods consumes about 1.2 MW of electricity and 3500 tonnes of carbon dioxide emissions per year [7]. As a drive to make JIC campus as zero emission places, it is the intent of this research to replace the conventional electric geysers by solar water heating systems. Using solar energy to heat water produces no harmful greenhouse gas emissions. It can provide up to 90 percent of total hot water requirements, as seen in Figure 8 and that indicate that EV or Solar-PV car parking can replace the conventional electric geysers by solar water heating systems. The proposed Green PV Car Parking See Fig. 7 will be the first in the city and will save a lot of power.

Fig. 7. Green PV car parking [5] (proposed).

VI. ANALYSIS OF PROJECT

As seen in Table VIII paybacks periods are within margin of 7 years for payback. The total carbon dioxide (CO₂) savings is 57 thousand ton approximately see Table VIII, an interesting indication comes from the comparison of CO₂ savings as seen in Figure 8 and that indicate that EV or Electric Vehicle saves the environment the most.

| Item                      | CO₂ Pollution Saving(Tone) | Payback period (Years) |
|---------------------------|---------------------------|------------------------|
| EV Car                    | 36,000                    | 1.6 months             |
| Solar Street Light        | 136.4                     | 7                      |
| Green PV Car Park (Namkoo)| 17,341                    | 7                      |
| Solar Heaters             | 3500                      | 6.3                    |
| Total                     | 57,000                    |                        |

Fig. 8. Comparison between CO₂ savings.

VII. CONCLUSION

JIC Green Initiative can save the environment 57 000 ton of CO₂ and will cover the electric bill of JIC by 97%, most of the systems including the solar system should payback within 7 years, as a result the project is financially feasible.

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