The Functioning of The Hybrid Integrated Partially Solar - Vapor-Compression Fridge

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Abstract: The main purpose of our research is to increase the utilization of solar thermal energy to supply a refrigerator with vapor compression and reduce the refrigeration power needed for cooling. Combined Hybrid Solar - the vapor- compression refrigerating unit has been built and operates under Mutah University's environment in Jordan. The systems were made up of a capillary tube, condenser, evaporator, and collector. The vapor-pressure refrigerator was incorporated with the classic water-solar system to minimize the compressor's duty and to reduce power consumption in heating the amount of water held in the pipe to be sent along the tube outside the evaporator. After that, it will be returned to the compressor, But at a lesser temperature, to minimize compressor workload and enhance cooling performance. Before the compressor was developed, a solar collector system had been created to maximize its temperature before reaching the compressor to improve C.O.P, and the difference in temperature was remarkable. The vapor-compression refrigerator unit was powered by many generators: solar collector that has been discharged, photovoltaic system, flat plate solar collector. Two groups of tests have been performed experimentally on the partial solar compression refrigerator integrated into a hybrid system. First in the vapor compression refrigerator only, and the second in the Hybrid solar compression refrigerator incorporated. Total sunlight and different temperatures, current, and voltage were measured for many months each hour of the day. The performance coefficient was determined found 2.019, 2.432 respectively. Many auxiliary instruments are utilized to measure the temperature in irradiation networks, voltage, and night-time current every hour.

Key-Words: - The vapor-compression fridge, Solar collector, compressor, hybrid, off-grid fridge, pilot solar hybrid PV/T unit, solid flow program, discharged solar collector, a voltage difference

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1. Introduction [1-4]

Among the greatest challenges in this century was refrigerating, storage, and preserving fast expiry material such as meat or milk and meals at lower temperatures without using electrical energy [1-2].

Due to its ability to cover a sufficient range of cooling and heating desired temperature by regulating pressure and lower process temperatures below ambient, a vapor compression refrigeration system plays an essential duty in the chemicals processing industry (CPI).

1.1 Refrigeration by Vapor Compression - an overview | ScienceDirect Topics [3-4]

The vapor compression process of refrigeration comprises four parts: an evaporator, an expansion valve/throttle valve, a condenser, and a compressor. This is a cycle of compression which purpose is to increase the pressure of coolant as it passes through the evaporator. The coolant with high-pressure passes via a heat exchanger \ condenser system before returning to the evaporator and reaching the first low pressure.

As stated below, a further description of the stages is given:

Step [1] : The Compression

The coolant (e.g., R-717) reaches the compressor with low temperatures and pressure. It is currently in the gas phase. Compression is utilized here to increase temperature and coolant pressure. The coolant liquid flows out of the compressor and goes into the condenser. As this procedure involves work, so an electrical motor might be employed. Compressors might be of the screw, scroll reciprocating, or centrifugal kinds.

Step [2]: The Condensation

Basically, the condenser is a heat exchanger. Thermal heat is transmitted from the coolant to a water flow, and water is then cooled when it comes to water-cooled condensation by the cooling tower. Remember that the seawater and techniques of air-cooling may perform that function, too. As the coolant passes by the condenser, the pressure is constant so that condenser protection and efficiency cannot be ignored. In particular, for effectiveness and safety reasons, so pressure regulation is essential. This need requires numerous pressure control mechanisms.

Step [3]: The Expansion and Throttling

When the coolant comes into the valve of throttle, the coolant expands and lowers pressure. Therefore, at this phase, the temperature decreases. Due to these alterations, the coolant usually escapes a vapor valve in amounts of approximately 75% and 25%, respectively, as a liquid-vapor mix. Throttling valves provide two key functions in the vapor compression stage. First, pressure variation between two sides of low and high pressure is maintained. Secondly, the liquid coolant in the evaporator could be regulated.

Step [4]: The Evaporation

During the vapor compression cooling process, the coolant has a temperature that is lower than the outside temperature. It therefore evaporates and absorbs residual vaporization heat. Heat absorption from the coolant occurs at low temperatures and pressure.The suction impact of the compressor helps to keep the pressure down. There are multiple evaporator types on the marketplace, but fluid and air refrigerating are the most important categories, and that based on whether we need to cool an air or a liquid.

The Performance Coefficient (COP) shows how effective this cycle is. Being aware that heat discharge is the refrigerator's purpose, the COP becomes (h) enthalpy.

Specific problems with the vapor compressing cooling cycle which might impact that value are:

Failure / Leaking of Compressor

The interruption of the industry cooling compressor may be costly and detrimental to the reputation of the manufacturer. Usually, manufacturers decompose discarded compressors in research fails. However, over the years of investigations, many frequent reasons were found for compressor interruption, including lubricating issues, overheating, lagging, pollution, and flood back.

Clogging – Condenser and Evaporator

Clogging is an isolator that slows transmission from the water to the coolant. It may develop through the growth of algae, precipitation, creation of scale, or mud. As this issue raises pressure, the energy consumption of the compressor may increase. So what are the best techniques? First, clean the evaporator surface and the tubes within the condenser. To put this issue away, water treatment technologies must be ready.

Motor Cooling

In the cycle of vapor compressing, the engine is undoubtedly the largest energy consumer. It is often due to efficiency falls in this unit the cooling issue. Many problems can cause blocking out in air filters to block out, Clogged filthy air passageways, etcetera. In particular, periodic reviews of the chiller records, in particular, a comparison between current and voltage, should reveal any abnormality.

Restriction of liquid path

Comprehension of the compression process is a crucial step to address common industrial cooling difficulties. The entire system's efficiency or general operation might be disrupted by all the parts engaged in the cycle. To detect upgrades inside your vapor compressing cooling cycle, ARANER could help you. This procedure comprises assessing the present state of the unit and prospective improvements. Other potential improvements for the system include the implementation of cooling tower modifications with high-efficiency system components. For these industrial cooling solutions, contact team.

1.1 Solutions and Technology for Solar Cooling [1-4]

Among Arab countries, the Hashemite Kingdom of Jordan has a sunny climate all through the year. So solar energy could be useful in summer, in particular. However, electricity comes from sources like petroleum and fossil fuels supplied from elsewhere. Therefore, converting electrical power into solar cooling systems in Petra, Wadi Rum, and other areas, mainly in Jordan Badia, by solar fridge cooling water to store tourism food without electricity need, especially some non-electricity-connected tourist areas [1-2].

The solar cooling system usually consists of three subunits the refrigerating system, the solar conversion system, and cooling pack. [3-5].

The overall efficiency [4]:

$$COP_{Solar} = \eta_{collector} \cdot \eta_{thermal} \cdot COP_{cycle} ,$$

$$\eta_{coll} = \frac{Q_{useful}}{Q} , \quad COP_{P_{el}} = \frac{Q_e}{W} , \quad COP_{thermal} = \frac{Q_e}{Q_g}$$

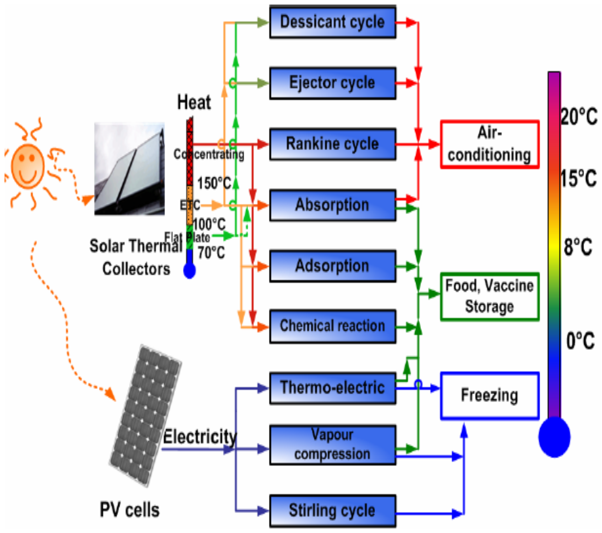


Figure 1. Solar Cooling Paths [4]

2. The hybrid refrigerator solar [1-4]

The hybrid variety employs electricity and solar energy; however, it uses the maximum amount of solar energy to operate the device to reduce your power cost. This means that the fridge consumes up to 44% less electricity.

Besides solar panels, a solar system suited for refrigerating applications needs other equipment. Batteries are required to store the electricity that the fridge will consume at night or when the sunlight is covered by clouds. The power flowing from panels to the battery is supplied by a device which is termed a charge regulator.

3. On/Off Pilot Fridge [1-6]

Food and vaccine preservation in various areas of the globe is an issue, especially if there is no electric power or is not constant for the protection of food and vaccines. This paper includes the many kinds of grid fridges, which were developed and operated within Mutah University south of Jordan to reduce and limit the dependence on electric power. However, most refrigerators are operated by electricity worldwide.

Adding a new source, which might be cooling without requiring power, could benefit those with a poor electrical supply. Many refrigerators are based on kerosene and have lately concentrated on solar cooling based on solar batteries [4-5]. Solar energy may be transformed into electric power and heat, alongside available solutions; the fridge is supplied by combined thermal energy and electricity [2], [6].

Off-Grid Solar Systems advantages

1. There is no way to connect to the power grid.
2. Off-grid solar solutions are cheaper than electricity cables in some remote regions.
3. Develop your ability to generate your own energy (self-sufficient).

Our research gives a brief overview of comparable analyses on hybrid combined solar-vapor-compression fridges partially.

- **On-Grid Vapor-Compression Fridge** Operated by electricity directly (the typical electrical fridge)
- Off-grid Fridge Operates With or Without electrical Power

Many off-grid integrated hybrid refrigerator units were developed, produced, and utilized at the Mutah University in South Jordan.

3..1. The Solar Pilot Evaporative Refrigerator

An off-grid, environmentally friendly pilot solar fridge was utilized to preserve and chill the vaccine storage and residential applications in Jordan Badia with no enough and dependable electricity supply. Various materials have been evaluated for the materials most appropriate for the interior and external surface of the refrigerator cylinder, such as iron, aluminum, wood, galvanized steel, taking their heat conductivity and their low-temperature production capacity into account.

As seen in figure 2, the refrigerator was constantly operated day and night throughout the month of the year; the outcome was encouraging, and the chilly interior was at the lowest temperature of 6 celsius.

The pilot solar refrigerator was also linked to a water storage reservoir to maintain the water level constant over time. During the refrigeration, several auxiliary devices were utilized to monitor and assess the effectiveness of the cooling. Many parameters, like surrounding and surface chamber temperature and refrigeration temperature, were listed in Figures 3-5.

Figure 2: Evaporative off-grid fridge

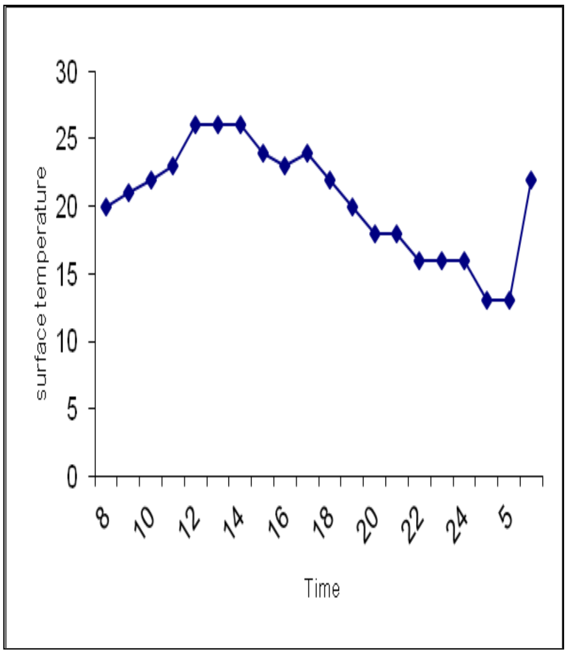


Figure 4 : surface chamber temperature

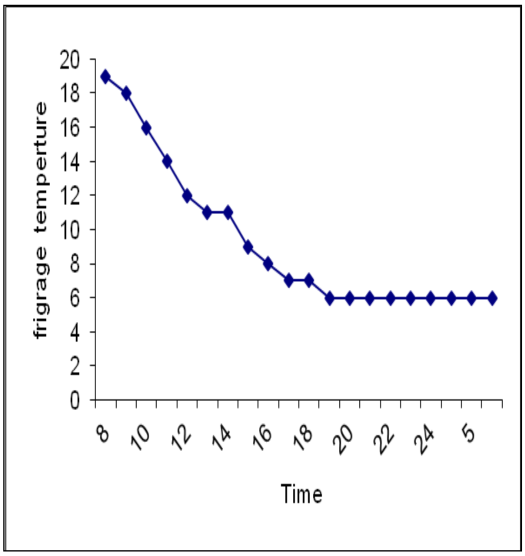


Figure 5: inside Fridge temperature

3..2. The pilot Hybrid Photovoltaic –Jordanian Solar Collector fridge [7]

In southern Jordan in Mutah University, the solar hybrid PV/T refrigerator unit, as seen in figure 6, was produced and placed into service. These PV/T systems transform the light intensity of photons to thermal energy and electricity. PV/T collection, electrical source, store tank, and circulation pump are the major parts of those systems. Analytically and experimentally assessed and reported the effectiveness of the pilot refrigerator. During the PV/T pilot refrigerator running, as illustrated in Figure 6-10, several parameters were monitored the total solar irradiation and the different temperatures at the inlet, inlet, ambient, and reservoir for many months each hour of the day. Besides, the pilot solar hybrid PV/T system was simulated employing the solid flow software utilizing the Fourth Order Runge-Kutta. On other hand several research did huge work on PV unit [22-27].

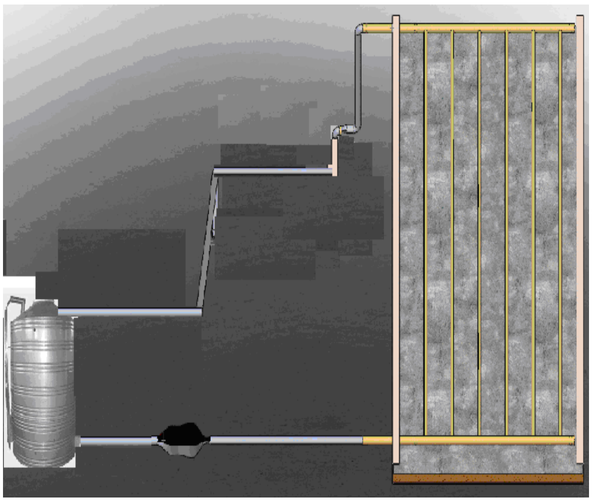


Figure 6: The pilot solar hybrid PV/T fridge unit

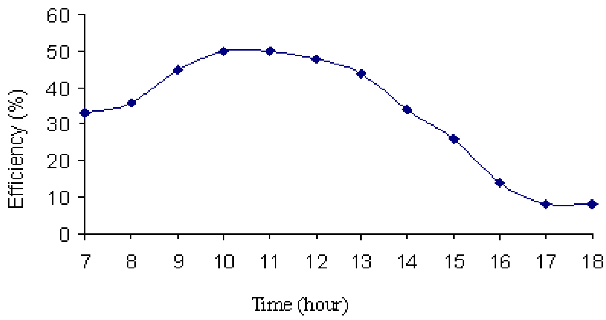


Figure 7: The **Generator heat exchanger availability**

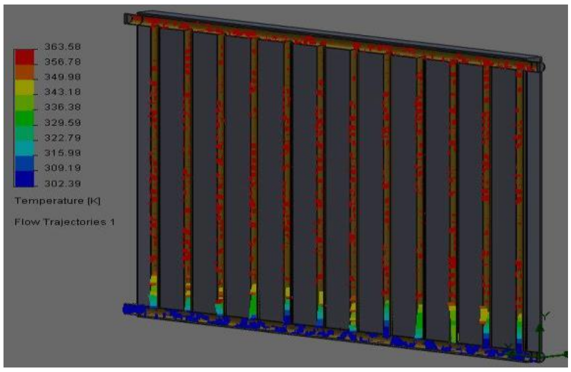


Figure 8: Simulated Temperature inside in the pilot (PV/T) fridge

3..3. Nano Adsorption Refrigerator Pilot Unit [8]

In the south of Jordan, a pilot's NANO adsorption refrigerator was developed and operated in Mutah University, as seen in Figure 11-14. The NANO Adsorption refrigerator's essential parts pilot is a vacuum pump, solar collector, condenser, and (cold chamber). The adsorption pair was activated carbon methanol. In addition, a unique selective nano-particle painting has been utilized to increase the accessibility and effectiveness of the plate in the absorber. The pilot refrigerator was continually operating for a few months daily, and many characteristics were checked and noted every hour, as seen in Figure 15. The fridge's inner temperature was 8 C, and chilled air was generated.

Figure 9:layout of the experiment fridge

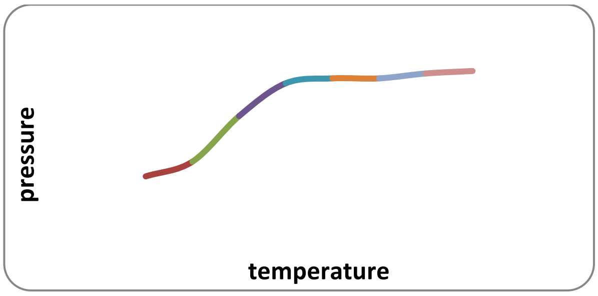


Figure 10: pressure versus temperature

- **Fridge Runs Partially With Electricity (Partially solar powered)**

Our research introduces a brief overview of comparable examinations on hybrid combined solar-vapor-compression fridges partially.

3..1. The Vapor-Compression Fridge [9-10]

4. Measuring equipment [14]

Several devices for temperature monitoring and recording, sun-light irradiance, the voltage differential between the main electric fridge house and current have been utilized:

- **THERMOCOUPLE** [14]:

The following parameters had been measured by each thermometer in the pilot hybrid electric-solar fridge house, as shown in figure 16:

- **Avo meter [14]:**

Solar Powered Vapor Compression Cooling System

Two schemes of PV panels were used to supply the compressor power.

1. PV panel converts solar radiation to DC power

Compression Refrigeration System Solar Powered Vapor

Photovoltaic panels transform the provided sunlight radiation into DC; into the typical vapor compressing system. Therefore, the system coefficient of performance is based on the Photovoltaic panel's effectiveness.

Solar power is a sporadic source and is not accessible all the time, so an alternate power source is needed if sunlight radiation is weak or is covered by clouds (Figure 5).

Klein and Reindl [6] studied the electrical properties generated by photovoltaic panels and compared them to the necessary compressor motor properties.

The most significant characteristic is the voltage, which should be near the voltage that produces the greatest power needed to run the system as efficiently as feasible.

This may be accomplished by several techniques to track the maximum power and then pick the electric motor which produces maximum current and voltage power

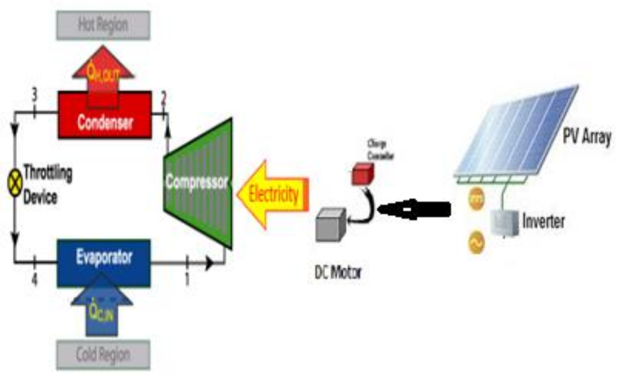


Figure 12: Solar Powered Vapor Compression process

PV/T Hybrid systems :

Solar collectors that transform sunlight radiation into electrical and thermal energy are called hybrid PV/T systems. These systems use a solar generator that collects the leftover energy and eliminates heat losses from the PV panel, integrating a photovoltaic cell that transforms electromagnetic radiation (photons) to electric power. Unfortunately, Photovoltaic (PV) cells suffer an efficiency reduction due to mainly increase resistance and rise in temperature.

This system could be designed to eject heat from PV cells and, therefore, reduce cells' temperature and improve their performance by decreasing resistance.

The standard water refrigerated thermal generator design employs panels on the rear of a PV unit. These pipelines are then fed by an operating fluid, generally glycol, mineral oil, or water. The PV cells heat is transmitted by the metal and absorbed by fluid (supposed to be lower than cell operating temperature). This heat is either expelled in closed-loop systems (for cooling it) or passed to a heat exchanger as it runs into its application. This heat is utilized or expelled in open-loop systems before the fluid goes back to the photovoltaic cells [4-8].

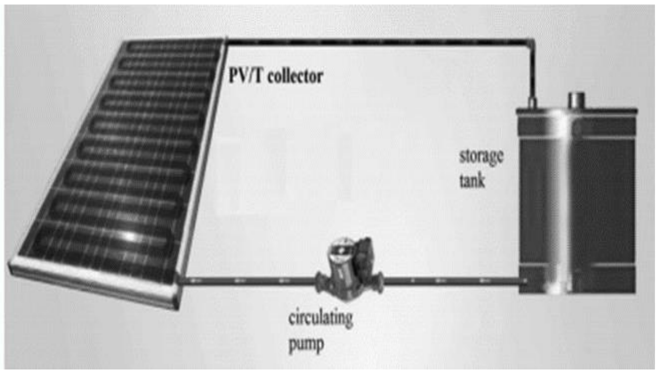


Figure 13: Integrated Hybrid Photovoltaic/Thermal -solar collector system [8]

The evacuated tube solar collector powering the compressor

Figure 1 depicts the installation of an evacuated pipe solar generator among the compressor and condenser. The solar generator comprises a very effective vacuum pipe that supplies some compression and thermal pressure by a further coolant overheating. The increased pressure and greater differences in temperature improve the condensation, thereby providing a high liquid coolant. By lowering the electric compressors load, this design significantly decreases energy usage.

The alternating current compressor is changed with the direct current compressor with good efficiency that needs significantly less power at the same load than the AC compressor [4].

A high torque motor without brushes drives the DC compressor, which is smaller and capable of running at variable speeds.

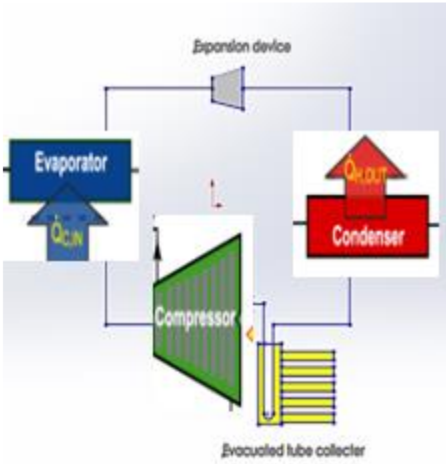


Figure 14: compressor powered by the use of the evacuated pipe solar generator.

By heating the coolant at constant volume, the Solar collector generates a compression pressure portion. According to the law of ideal gas, PV=nRT, P is the absolute pressure of gas,

T is the gas's absolute temperature, R is the constant of ideal gas, n is the mole's number in gas, and V is the volume of gas.

The solar pipe collectors comprise many tubes made of glass which has the air expelled, generating a vacuum between the surfaces of the glass tube and the absorber.

The vacuum layer eliminates the loss of heat via convection and conduction and makes radiation the only mechanism for heat loss [7].

The U-tube evacuated solar generator is made out of a long copper tube that guides the coolant flowing through the evacuated tube.

This offers a larger heat exchange area, which is extremely useful due to the poor conductivity of refrigerant vapor.

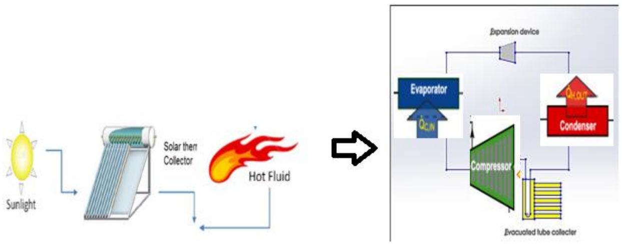


Figure 15: **compressor powered by flat plate solar generator.**

5. Result & Discussions:

By introducing partially/entirely off-grid friendly environmentally source powered fridges, the main goal of this research is to develop the energy production by utilizing solar generators that will be utilized as input thermal energy in the vapor-compression fridge and reduce the consumed electrical power by the integrated refrigerator cooling fridge.

Two categorises of refrigerators were examined and evaluated: the first was an on-grid traditional electrical fridge house, and the second was a hybrid electrical-solar fridge home. The prototype Combined Solar Hybrid- the vapor-compression fridge has been produced and operated at Mutah University in Southern Jordan. The pilot refrigerator was made using a condenser, solar generator g unit, capillary tube, and heat exchanger. Many auxiliary measuring devices have employed for measuring the voltages and temperatures of a thermocouple and AVO meter, including the Pyrometer, utilized for measuring solar radiation.

- **Components of the vapor-Compression Refrigerator Unit.**

Figures 3-7 show the cooling system's parts (expansion valve, capillary tube, condenser, evaporator, compressor).

5..1. The Refrigerant [4]

There are many fluorocarbon coolants developed for VCRC need: R134a, Freon-12, R141b $C_2H_3FCl_2$, R290 (R-12), R744 CO_2, R22 CH ClF_2,

Figure 16 show the electrical **vapor-compression fridge thermal cycle**

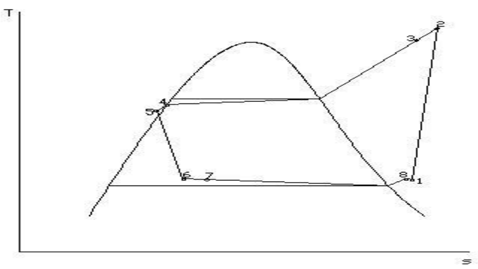


Figure 16: Fridge thermal cycle [11]

5..2. The evaporator

5..3. The Expansion Valve [12]
5..4. Capillary Tube [12]
5..5. The Compressor [8]

5..6. The Condenser [4]

The electric vapor-compression refrigerator thermal cycle is shown in Figure 16.

- 1-2 Gas compression in the compressor.
- 2-3 Piping losses.
- 3-4 Heat rejection in the condenser is near needs constant pressure.
- 4-5 Piping losses.
- 5-6 throttling in an expansion valve.
- 6-7 Piping losses.
- 7-8 Heat addition in the evaporator is nearly constant pressure.
- 8-1 Piping losses.

And

- T_{tank}: water tank Temperature
- T_9**:** R-12 compressor inlet temperature.
- T_8**:** R-12 storage reservoir outlet temperature.
- T_7**:** R-12 storage reservoir inlet temperature.
- T_6**:** R-12 evaporator outlet temperature.
- T_5**:** Temperature of water within the evaporator
- T_4**:** R-12 condenser outlet temperature.
- T_3**:** R-12 condenser middel temperature.
- T_2**:** R-12 condenser inlet temperature.
- T_1**:** R-12 compressor outlet temperature.
- T water - cold: Cold water temperature
- T feed: Feed water temperature
- T water - hot: Hot water temperature
- T cond - mid: Condenser surface temperature at the center
- T cond - inlet: Surface temperature of the condenser at the inlet
- T cond - exit: Surface temperature of the condenser at the outlet
- T evap - Inlet : Evaporator surface temperature at inlet
- T evap - exit: Evaporator surface temperature at the outlet

The voltage variation of the main electrical refrigerator house is recorded regularly every 4 hours in 17 hours using an AVO meter.

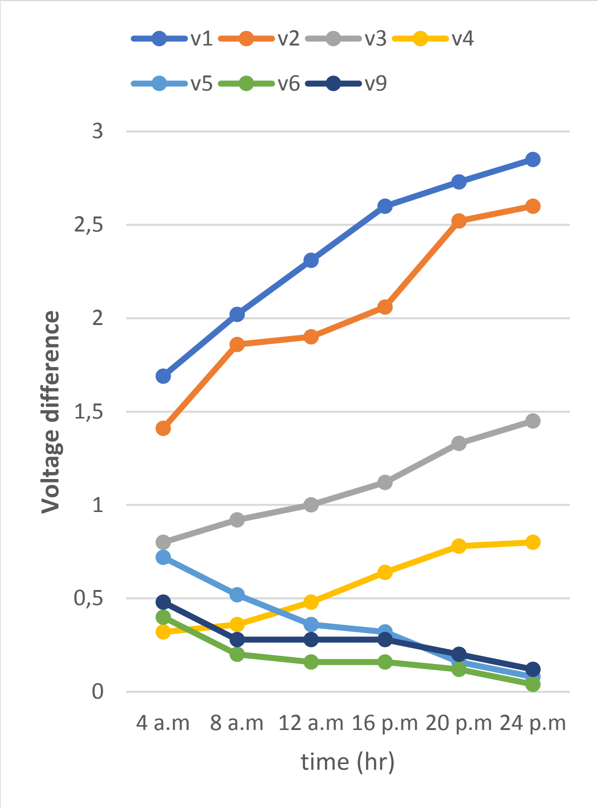


Figure 17: **Voltage difference across electrical fridge house**

As seen in Figure 18, the temperature records for the electric refrigerator calculated.

Figure 19 depicts the rate of heating for every single unit, whereas Figure 20 depicts the matching COP across the refrigerator house part.

$$\Delta T = \sum_{n=0}^{N} \upsilon^n a_n$$

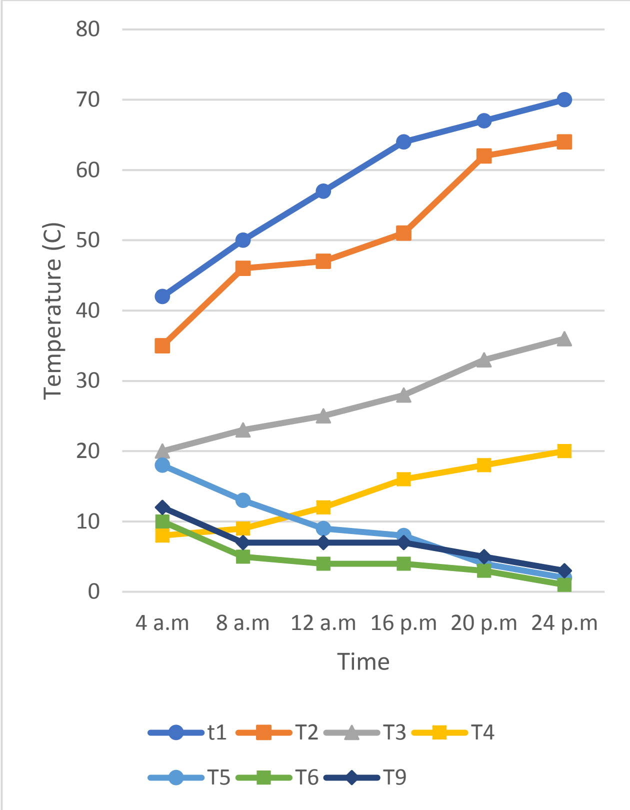


Figure 18: **Temperature across the conventional vapor-compression fridge house**

The rate of heating of all devices are seen in figure 19 and corresponding COP are seen in figure 20 across the fridge house component are reported figure 20.

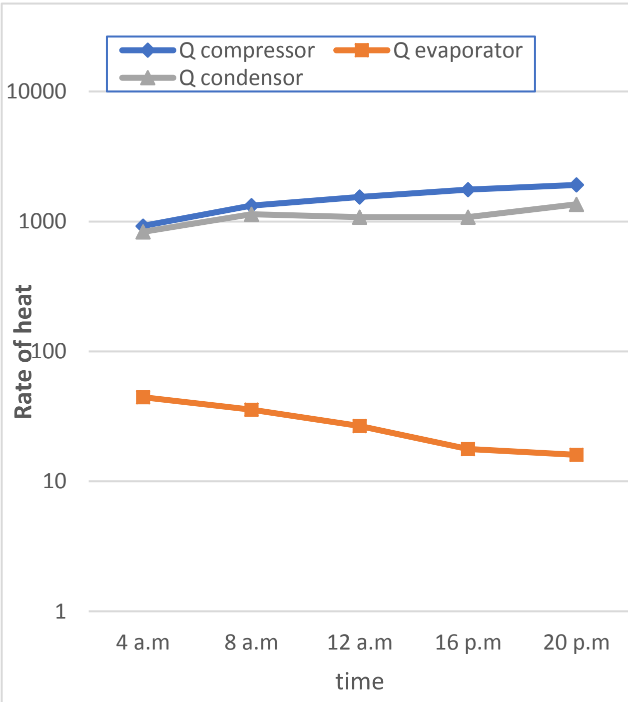


Figure 19: **Rate of heating to each device across the conventional vapor-compression fridge**

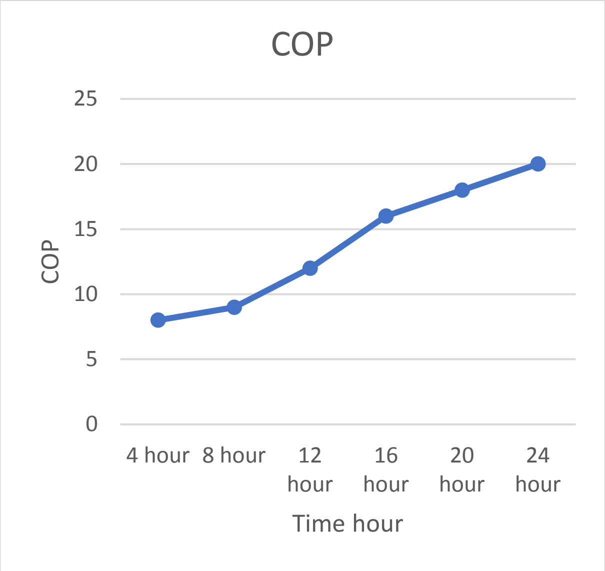


figure 20: coefficient of performance of electrical vapor compressor fridge

power input P = IV ....(14)

and

$I_{average}$ =0.1 A,

$V_{average}$ =220 Volt

P= 0.1×220 = 22 Watt per hour

Electricity consumption costs (QEC) is:

QEC= Power× number of working hours × Depreciation fils ......(15)

QEC= 22×4×32 = 28.16 fils/day= 5.06 JD/month= 60.24 JD/year, (JD=1.4 USA)

- **The Pilot hybrid Integrated Solar - Vapor-Compression Fridge**

The solar-vapor-compression refrigerator combined in the pilot hybrid, as seen in Figures 21-22, has been tested in winter even with low solar irradiation.

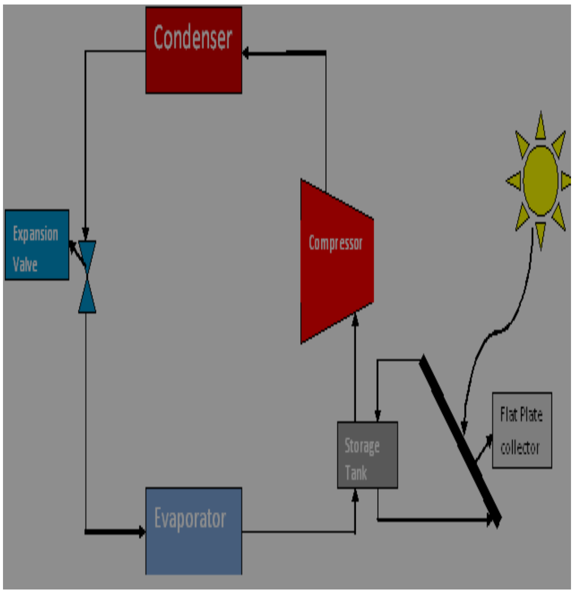
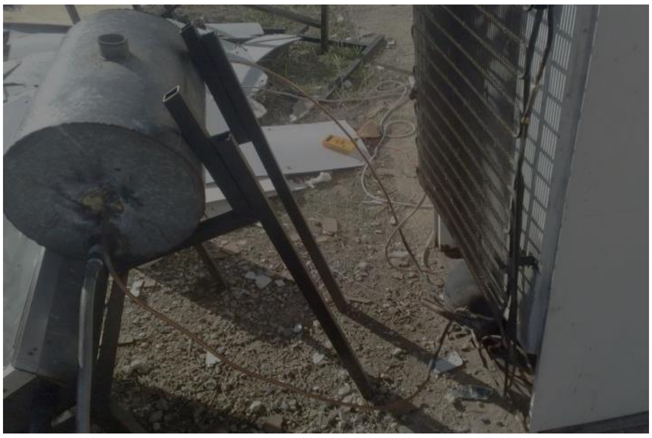


Figure 21. The pilot hybrid integrated Solar vapor compression fridge



1.2 Figure 22. The pilot hybrid integrated Solar- vapor-compression fridge

Before the compressor was introduced, a solar collector system increased its temperature to raise its C.O.P earlier than the compressor was reached, and the temperature difference was achieved.

The thermal gain from the storage reservoir was utilized for heating R12 gas that leaves the evaporator, therefore reducing compressor effort and power from the evaporator before entering the compressor.

Because the thermal energy obtained by the storage reservoir raises the temperature of R12 gas, the compressor's effectiveness improves as a consequence of requiring less power.

Figure 18 shows the Hybrid Electrical-Vapor-Compression Refrigerator Analysis.

The R12 vapor rejected thermo-energy by the condenser is equivalent according to thermodynamic rules to The R12 vapor absorbed the evaporator's thermal energy [16]:

Collector of flat plate Analysis [11-22]

The energy absorbed by the generator [15]:

$S = I_b R_b (\tau\alpha)_b + I_d(\tau\alpha)_d (1+\cos\beta) / 2 + \rho_g (I_b + I_b)(\tau\alpha)_g (1-\cos\beta) / 2$ (1)

Where,

I_b the beam and I_d the diffuse radiation, and could be calculated as follows

$I_b=\tau_b.I_o$ (2)

$I_d=\tau_d I_o$ (3)

I_o the sunlight radiations that reach a horizontal surface, and could be calculated as follows:

$I_o= (12\times3600/\pi)G_{sc} \{1+0.033\cos(360n/365)\}$

$\times\{\cos\varphi\cos\delta(\sin\omega_2-\sin\omega_1)+(\pi(\omega_2-\omega_1)\sin\varphi\sin\delta)/180\}$..(4)

Heat Exchanger Condenser Calculation

The R12 vapor rejected thermal energy which comes from the condenser is:

$Q_{hr}=m_v(h_{v2}-h_{cd})$ (5)

Where,

m_v: the vapor mass of R12,

h_{v2} : the R12 vapor enthalpy,

h_{cd}: the condensed R12 liquid enthalpy.

According to thermodynamic laws, The R12 vapor rejected thermal energy from the condenser is equal The R12 vapor absorbed thermal energy by the evaporator [16]:

$m_{cw}\, cp_w\, \Delta T_{cw}=m_v (h_{v2}- h_{cd})$ (6)

where

m_{cw} the entire cooling water mass needed for the condenser,

cp_w is the cooling water's specific heat

ΔT_{cw} Rising cold water temperature.

- **Evaporator Calculation**

The thermal energy absorbed by the evaporator in vapor R12 equates to the thermal heat amount extracted from pure R12 liquid besides the water surrounding the recipient.

The formula of the energy balancing is, therefore:

$m_{av}\, h_{fg} =cp_a\, m_{ca} (T_{c1}- T_{c2}) + Cp_w\, m_{eq} (T_{c1} -T_{c2})$ (7)

Where

T_{c1} & T_{c2}: preliminary and last temperatures in the generator

cp_a & cp_w: specific heat of pure R12 and cold water

m_{eq} :mass of the cold water,

m_{ca}: mass of the remaining pure R12 liquid within the evaporator.

h_{fg}: Evaporation latent heat of pure R12,

m_{av}:-vapor mass of R12

The last evaporator temperature is:

$$T_{c2} = T_{c1} - m_{av} h_{fg} / (m_{ca}.cp_a + m_{eq}.cp_w) \quad (8)$$

- **Compressor calculation**

The energy balance across the compressor

$$Qc = m_r(h_2 - h_1) + P_s = m_r\, Cp(T_2 - T_1) + \nu\Delta P \quad (9)$$

- **Coefficients of Performance (Cop)**

The performance coefficients are the heat removal ratio of the compressor to the energy input.

$$\text{Actual C.O.P} = Q_e/P_eI \quad (10)$$

$$\text{Theoretical C.O.P} = (h_1 - h_4)/(h_2 - h_1) \quad (11)$$

- **The Global Irradiance**

the global, diffused radiation on a stabilized surface with clear sky (W/m2) as seen in figure 23.

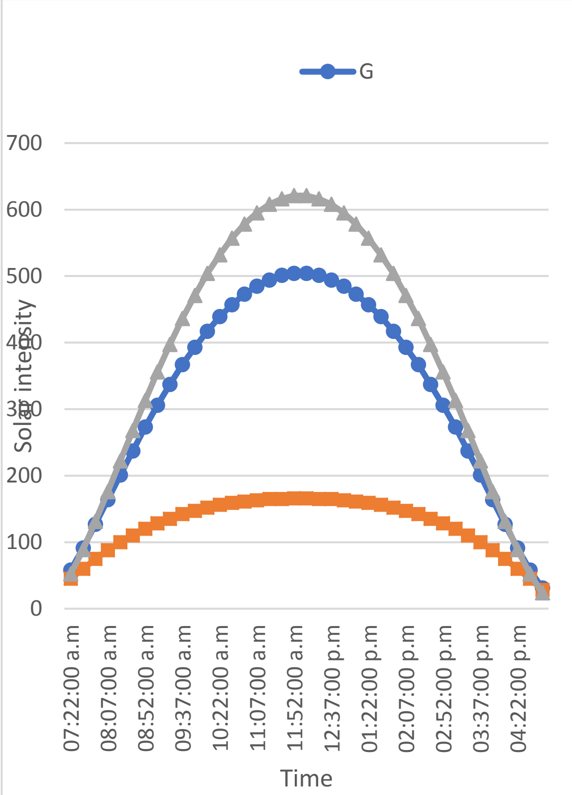


Figure 23 **Global clear-sky** irradiance on a fixed plane and global diffuse (W/m^2)

and

G: Is the global irradiation on a stabilized surface (W/m2)

Gd: Is the global diffused radiation on a stabilized surface with a clear sky (W/ m2)

Gc: Is the global clear-sky irradiation on a surface (W/ m2)

The voltage record in the hybrid electric-solar refrigerator as seen in figure 24.

The average temperature of the hybrid electrical-solar fridge home is apparent in Figure 25.

Figure 24 shows the voltage records in the hybrid electrical-solar fridge house.

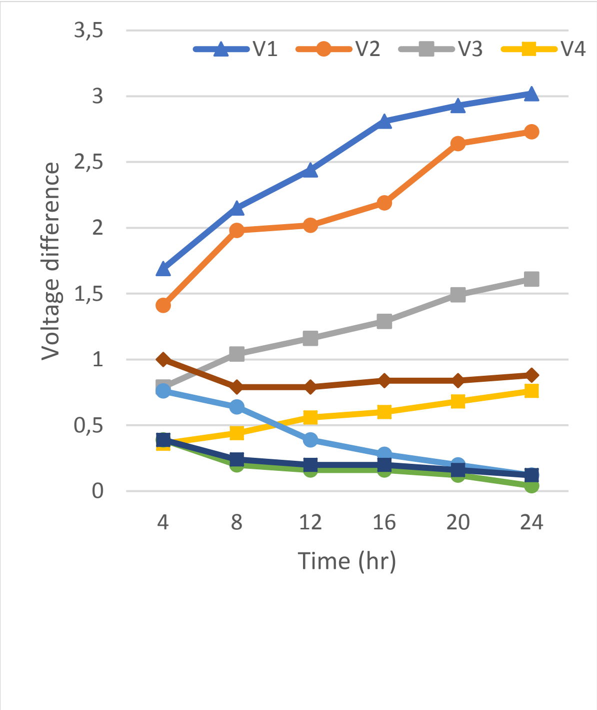


Figure 24: the voltage over the hybrid electrical-solar fridge home

Figure 25 shows the average temperature of the hybrid electrical-solar fridge home.

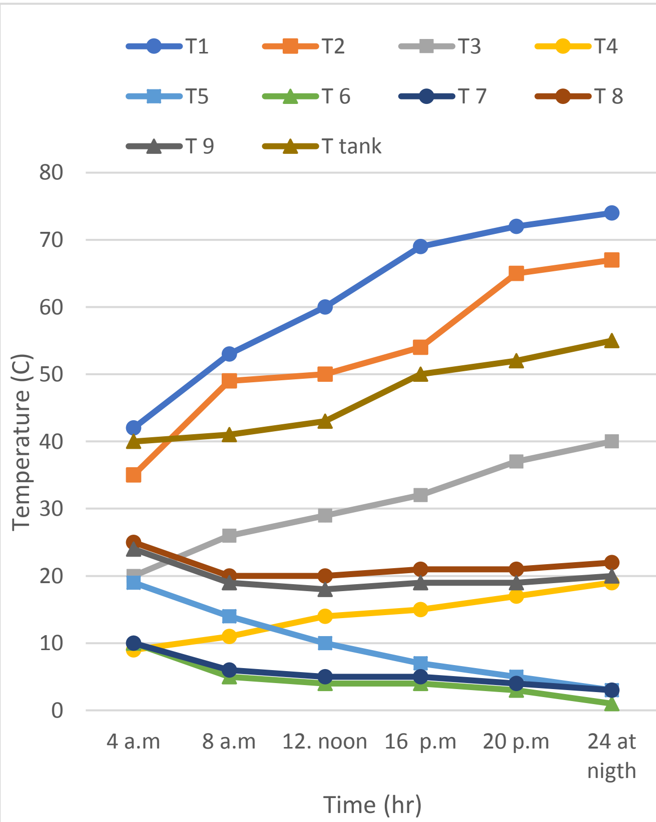


Figure 25 Temperature values over the hybrid electrical-solar fridge home.

While figure 26 shows the heating rate for every unit and COP

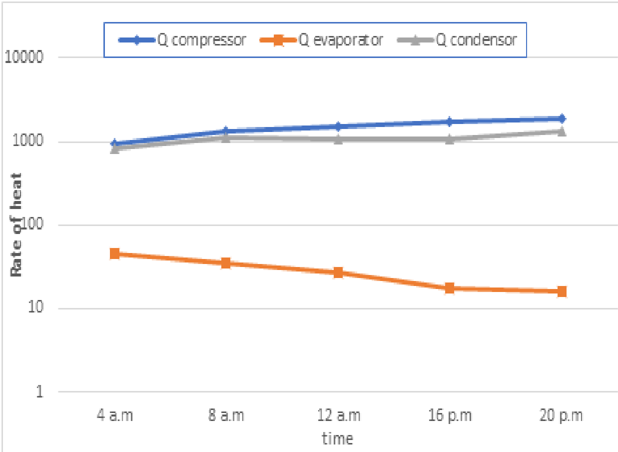


Figure 26: **Rate of heat of every device across the pilot Hybrid integrated partially Solar-conventional vapor-compression fridge**

Figure 27 depicts the prototype Hybrid's performance coefficient of partially integrated solar-conventional vapor compression refrigerating.

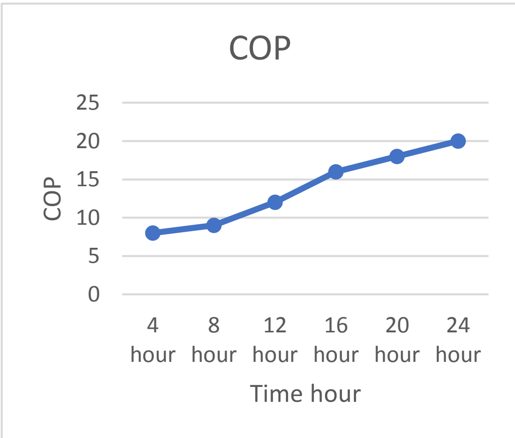


Figure 27: performance coefficient of the pilot hybrid integrated partially Solar- vapor-compression fridge

$I_{average}$ =0.083 A, and $V_{average}$=220 Volt

P= 0.083×220 = 18.26 Watt per hour

QEC= 18.26×4×32 = 23.37 fils/day = 4.21 JD/month = 50.52 JD/year

Before utilizing the solar generator, the performance coefficient for the electric refrigerator home was 2.019, and the coefficient for the hybrid solar electric refrigerator after connection of the solar generator with the fridge was 2.432.

6. Study of Feasibility

The - vapor compression refrigerator was 22 Watt per month consumed by the compressor. On the opposite side, after using an integrated solar collector with the refrigerator house, the prototype hybrid compressor was partially combined into the solar-vapor-compression refrigerator using 18,26 Watts/month, therefore achieving 1.74 watts per month (20,88 watts/year).

7. Conclusion:

This research introduces realistic details on the prototype hybrid partially integrated Solar vapor-compression refrigerator developed and utilized in Mutah University in the south of Jordan.

As clear proof, Jordan may offer a significant energy-saving result by combining positive and active solar technology.

The hybrid combined partially Solar-vapor-compression refrigeration unit has been designed and evaluated. During the winter and summer, the system is examined, it gets more effective.

The performance coefficient was 2.019 before the solar generator was installed, and after solar collector integration, it was 2,432.

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Mohammed Al-Dabbas graduated from faculty of engineering from university of Jordan. He was worked in Ministry of energy as head of renewable energy (1992-2004). In 2005 he staring work as an Associate Professor in Mutah University, Karak, Jordan.

He was publishing several article solar energy, wind, geothermal energy, oil shale combustion and hydrogen., 3D printing, nano technology, solar chimney

He was achieved 4 prize

1. the winner of the International Prize for Arab scientists in renewable energy
2. Zinc Innovation campus
3. golden prize of the National Technology Parade in industrial sector
4. ITISAF prize in renewable energy

He was register 4 patent in solar cooling especially in production of ice from sun without using electricity:

1. a mixture of paint and nano-materials for enhancing the performance of absorption and adsorbtion solar cooling systems

2. a solar refrigerator and ice maker by harnessing the evaporative cooling effect

3. oil shale fridge