# Challenges Facing the Future of Power Systems

**Jordan Cigre National Committee**

**24th- 25th April 2018**

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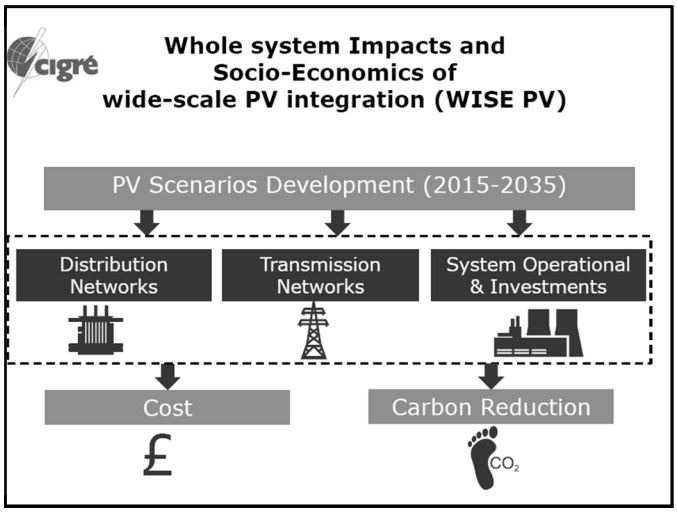
The main mission of the JCNC is to facilitate the exchange of the latest electrical power systems' researches carried out in the region to:

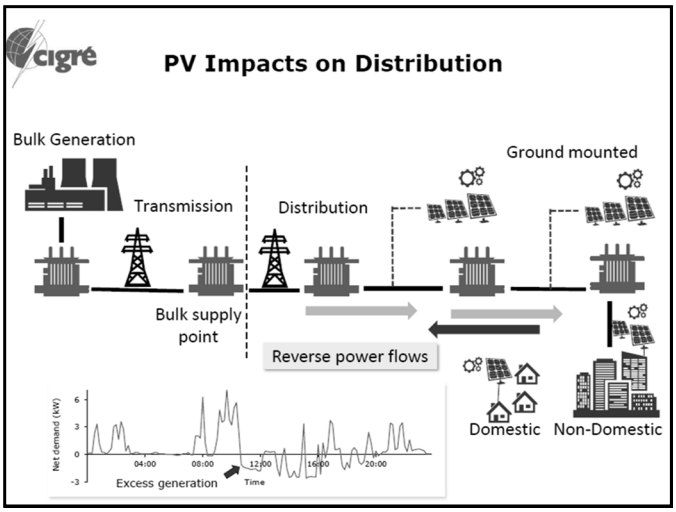
- Allow engineers and specialists from all around the world to exchange information and enhance their knowledge related to power systems,
- Add value to the knowledge and information exchanged by synthesizing state-of-the-art world practices,
- Make the synthesis of Cigre's work available to the decision-makers of the industry.

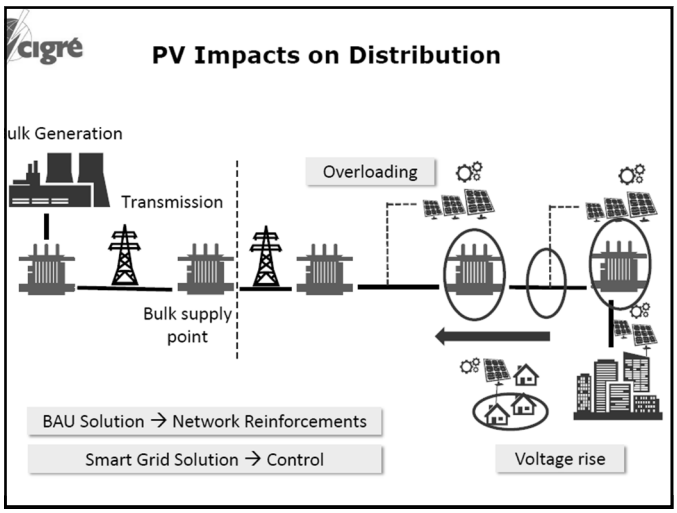
**Conference Topics**

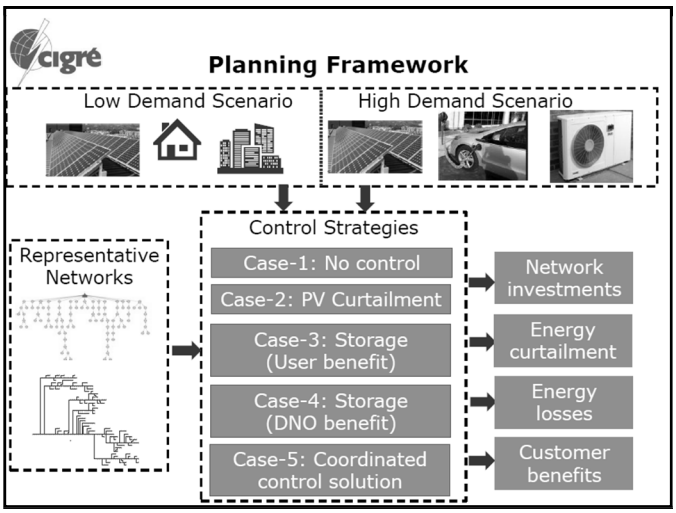
1. Sources of primary energy.
2. Technical and technological trends
3. Regulatory Issues
4. Economic and Financial constraints
5. Environmental considerations

**Grid Impact Analysis and Smart-Grid Control Strategies for PV-Rich Distribution Networks**


Whole system Impacts and Socio-Economics of wide-scale PV integration (WISE PV)
PV Scenarios Development (2015-2035)
Distribution Networks
Transmission Networks
System Operational & Investments
Cost
£
Carbon Reduction
$CO_2$


PV Impacts on Distribution
Bulk Generation
Transmission
Distribution
Ground mounted
Bulk supply point
Reverse power flows
Domestic
Non-Domestic
Net demand (kW)
Excess generation
Time


PV Impacts on Distribution
ulk Generation
Transmission
Overloading
Bulk supply point
BAU Solution → Network Reinforcements
Smart Grid Solution → Control
Voltage rise

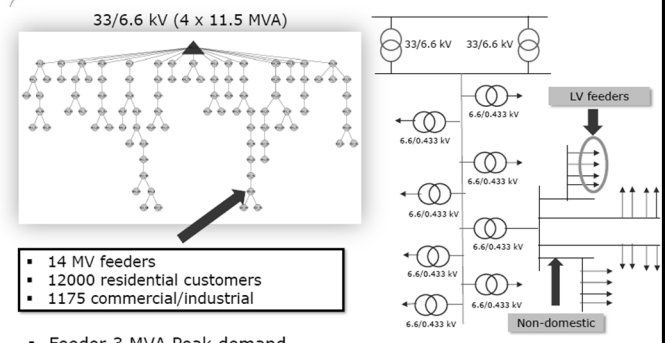

Planning Framework
Low Demand Scenario
High Demand Scenario
Representative Networks
Control Strategies
Case-1: No control
Case-2: PV Curtailment
Case-3: Storage (User benefit)
Case-4: Storage (DNO benefit)
Case-5: Coordinated control solution
Network investments
Energy curtailment
Energy losses
Customer benefits

## Results Outline

- Real urban MV/LV network at low demand scenario
  - Case 1 : No control
  - Case 2 : PV curtailment
  - Case 3 : Storage (user benefit)
  - Case 4 : Storage (DNO benefit)

DNO: Distribution Network Operators
MV/LV network from UK distribution system

## Real MV/LV Urban Network




- 14 MV feeders
- 12000 residential customers
- 1175 commercial/industrial

- Feeder 3 MVA Peak demand (winter)
- 1.2 MVA minimum demand (summer)

LV networks are explicitly modeled → Unbalanced three phase power flow

## Conclusions

### Urban

- With low demand PV triggers LV investments but no MV investments
- High demand triggers LV reinforcements thus PV related investments are only for very high penetrations
- PV management avoids reinforcements due to PV but at the expense of energy curtailment (less with high demand)

–This can be reduced with other technologies (OLTCs, storage)

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### Rural

- Ground mounted PV drives MV network investment for both low and high demand
- PV management also avoids reinforcements

–Large volumes of domestic PV increases ground mounted PV curtailment

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- Domestic-scale storage controlled for the benefit of the customer does not solve network issues

–Significantly increases self-energy sufficiency → consumers become more grid-independent

- Domestic-scale storage controlled for the benefit of the DNOs solves network issues and reduce the need for energy curtailment. However, it reduces self sufficiency of residential customers (incentives schemes may be required)

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**Smart Grid Experiences of Korea**

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What does Smart Grid means? July 2009

At the level of the customer:

–Meters that can be read automatically

–Time-of-day and time-of-use meters

–Meters that communicate to customers

–Control of customers' loads

At the level of the distribution system:

–Distribution system automation

–Selective load control

–Managing distributed generation and "islanding“

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At the level of the transmission system:

–Measurement of phase and other advanced measurements

–FACTS and other advanced control devices

–Distributed and autonomous control

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What does a Smart Grid do?

- The Smart Grid represents an unprecedented opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health.
- During the transition period, it will be critical to carry out testing, technology improvements, consumer education, development of standards and regulations, and information sharing between projects to ensure that the benefits we envision from the Smart Grid become a reality.

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The benefits associated with the Smart Grid include:

- More efficient transmission of electricity
- Quicker restoration of electricity after power disturbances
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers
- Reduced peak demand, which will also help lower electricity rates

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- Increased integration of large-scale renewable energy systems
- Better integration of customer-owner power generation systems, including renewable energy systems
- Improved security

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Various Electric Power Source


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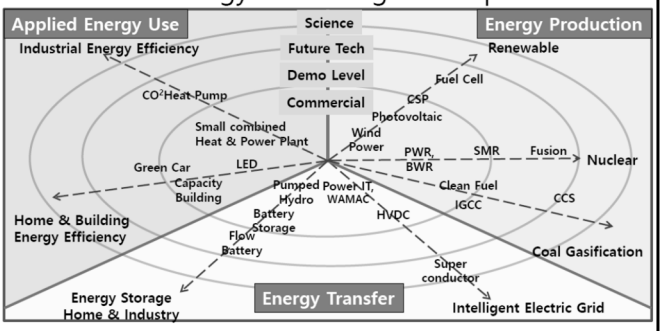
## 360° Green Energy Technologies Perspective

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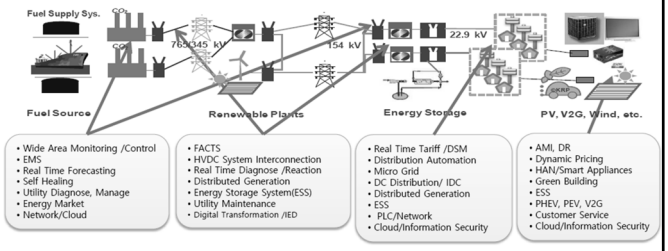
## Issue of Smart Grid

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## PV Impacts on Regulated Utility

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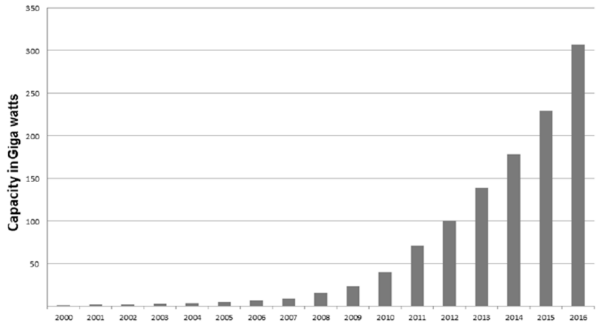
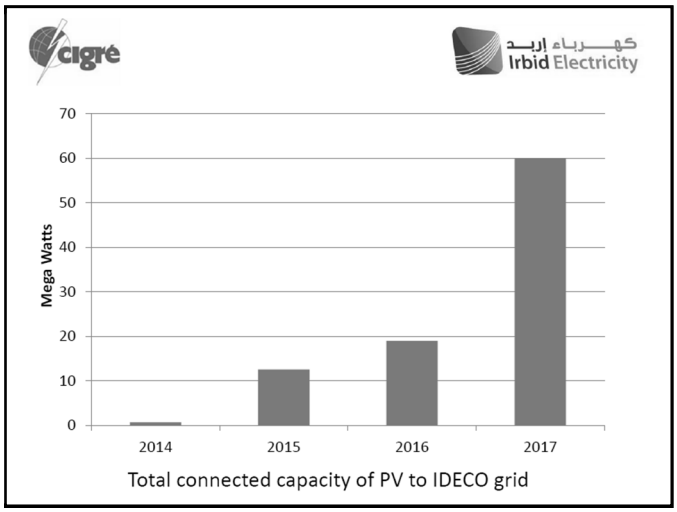
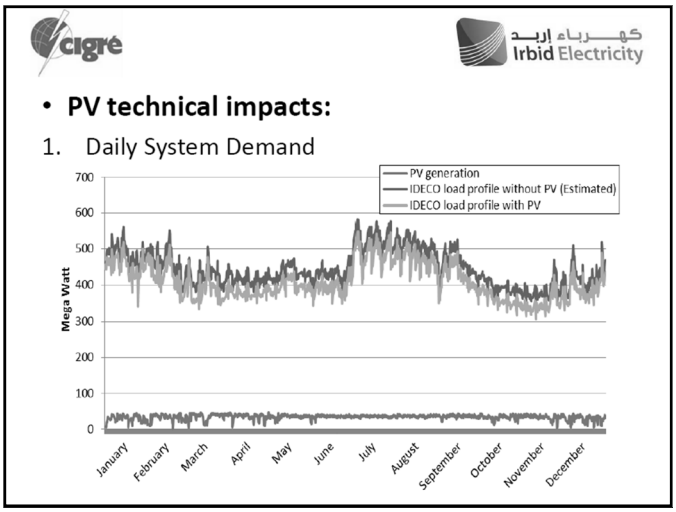
Irbid Electricity

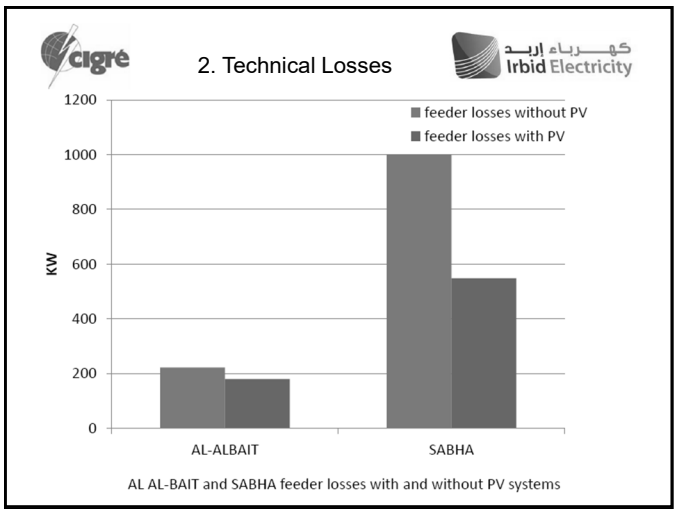
- **Introduction:**

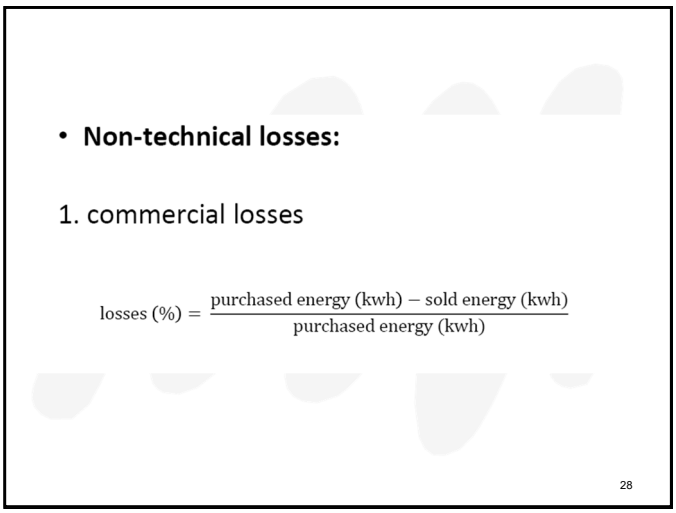



Global installed solar PV capacity


Mega Watts
70
60
50
40
30
20
10
0
2014
2015
2016
2017
Total connected capacity of PV to IDECO grid


• PV technical impacts:
1. Daily System Demand
PV generation
IDECO load profile without PV (Estimated)
IDECO load profile with PV
Mega Watt
700
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December


2. Technical Losses
feeder losses without PV
feeder losses with PV
KW
1200
1000
800
600
400
200
0
AL-ALBAIT
SABHA
AL AL-BAIT and SABHA feeder losses with and without PV systems


• Non-technical losses:
1. commercial losses
losses (%) = purchased energy (kwh) − sold energy (kwh) / purchased energy (kwh)
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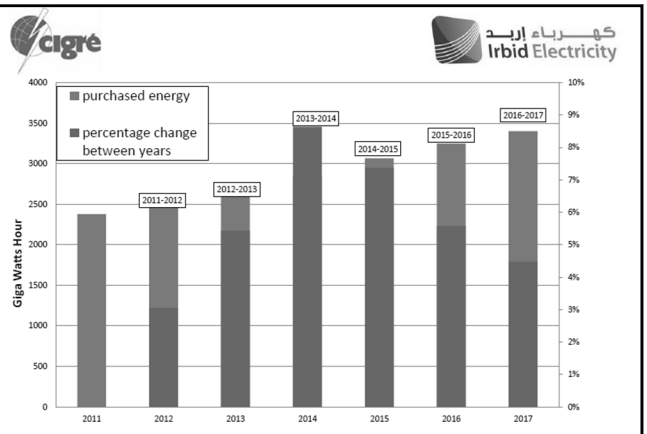
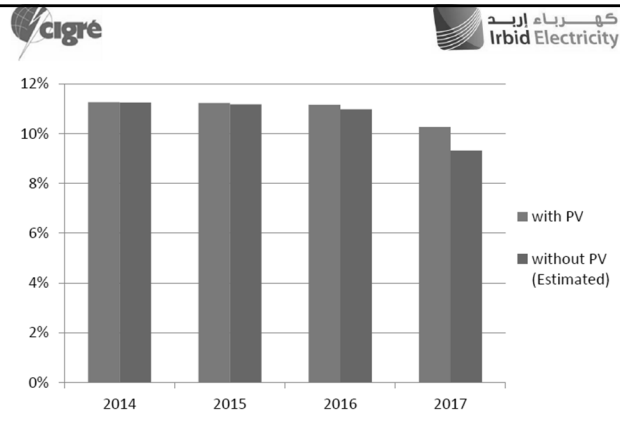



Total purchased energy of IDECO grid and the percentage of increase of the purchased energy in 2011 until 2017




System losses with and without PV

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**Conclusions**

1. PV systems decreases the daily system demand of the system connected to.

2.As PV connected capacity increased, the technical losses of the system decreased.

3.As the PV connected capacity increased the commercial losses increased.

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**Converting the building of the Higher Council for Science and Technology into a green building**

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**Jordan Energy Policy**

- According to the 2007-2020 energy strategy: Jordan aims to reach 7% of renewable energy in the primary energy mix by 2015 and 10% by 2020.
- This strategy is currently under reviewing to be replaced by a new one 2015-2025 which calls for 20% RE.
- The energy strategy has included a target of 20% improvement in energy efficiency by the year 2025.

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**The Main Challenges of Energy Sector in Jordan**

- Almost **no** local energy resources
- Highly dependency on imported energy, **Approx. 95% import in 2017)**
- High cost (The energy imports accounted for 17.6% of GDP in 2014 and 9.5% in 2015)
- High growth of primary energy demand.

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- **Jordan** imports 96% of its oil and gas, mostly at global market prices, while simultaneously striving to expand **energy** services for its growing population and economy.

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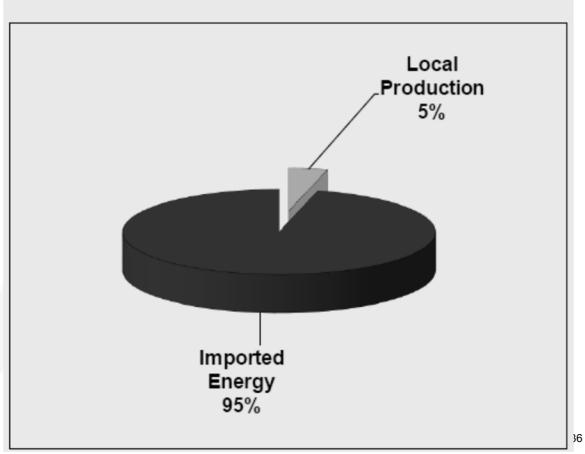


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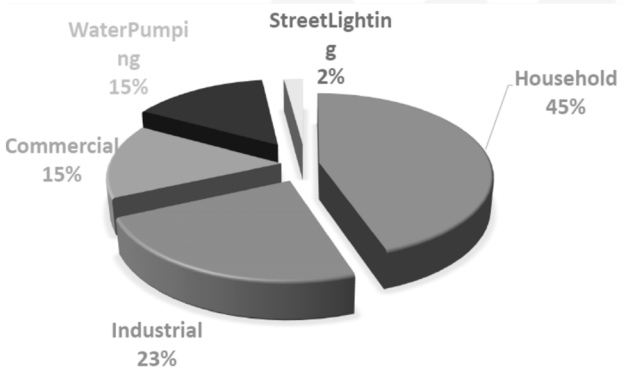
**Electrical Energy Consumption**




**Converting the building of the Higher Council for Science and Technology into a green building**

Objective:

- The objective of the project is to reduce the cost of energy consumption, improve the environmental situation of the building through the transition to environmentally friendly technologies, increase the comfort of employees working in the building and thus increase their productivity.

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**Renewable energy and energy efficiency measures**

In this project, four RE and EE measures were implemented :

1- Space heating and cooling and domestic hot water using geothermal heat pumps (Ground Source Heat Pumps, GSHP).

2- Replacing of old fluorescents into energy-saving units (LED).

3- Replacing of old single glazed windows with double glass and using of thermal insulation for some parts of the building.

4- Installation of solar photovoltaic system (52 kWp) on the roof of the building.

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**On-grid Solar PV system for HCST**

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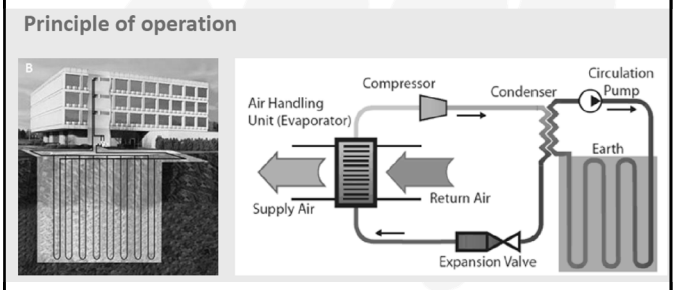
Ground Source Heat Pump: success story of Higher Council for Science and Technology building

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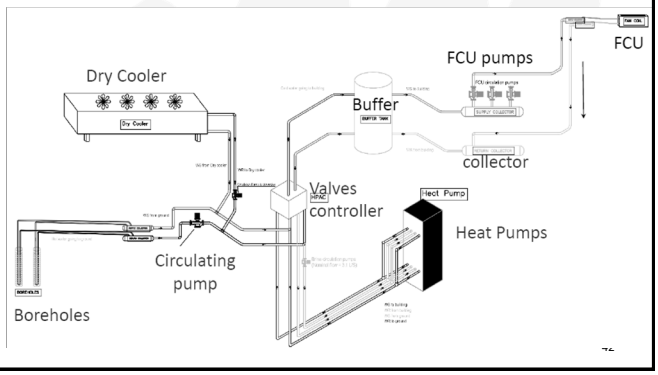
Closed- Loop Ground-Source Heat Pump system (GSHP)




**Conclusion**

A Ground Source Heat Pump was successfully installed at the Higher Council for Science and Technology (HCST) building.

- Total heat pumps capacity =300 kW.
- Saving = 45% as compared with the old split units
- Solar Photovoltaic system = 52 kW peak

The financial analysis:

- Payback period =7 years
- Net present value for the lifetime of the systems = 471,000 JD

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**The Relationship Between Very Fast Transients and Solids Dielectric Thermal Breakdown**

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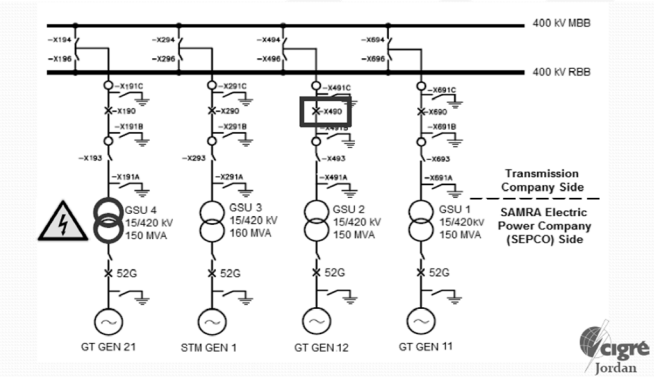
## Case Study

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GT21 main transformer high voltage bushing (red-phase) explosion incident

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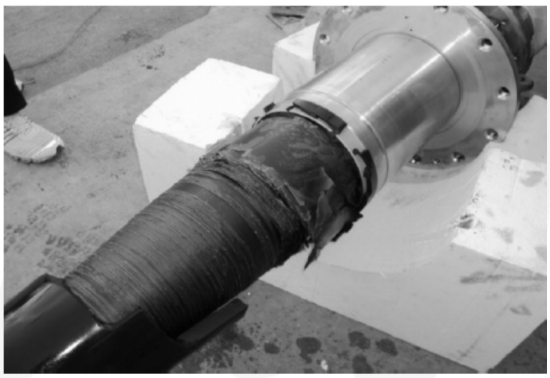

Oil-side porcelain part of GT21 main transformer (red phase) high voltage bushing after incident

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**Very fast transient (VFT) as a cause of bushing failure:**

- Very Fast Transient rise-time.
- Incident Timing.
- Unwinding Tests Results.
- Preventive Tests Results.
- Hence, it can be concluded that the most significant and effective variable at the energy equation was the frequency resulted from the very fast transient wave.

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In our case, all bushings were capable to dissipate the generated energy except the bushing of the (red phase) on the main transformer of GT21 and this would be explained through the following reasons:

- Bushing breakdown Nature.
- Bushing creepage distance inappropriate selection.
- Porcelain manufacturing deformation.

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**Conclusion**

- The over voltage (VFT) surge was confirmed to be the main cause for the (OIP: Oil Impregnated Paper) bushing thermal breakdown, in addition to inappropriate and deformation of the (OIP) bushing which includes the outer surface, insulator thickness and the creepage distance of the bushing porcelain.

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**Recommendations**

- The QC report of the bushing should take in consideration the checking of the outer surface, thickness and creepage distance and their compatibility with the designed values.
- The QC reports must be reviewed carefully by the purchaser before the installation process.
- Installing an extra creepage distance for the bushing in order to overcome the increasing site pollution severity caused by nearby future projects.

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- The controlled switching method is proven to be one of the methods that minimize the effect of the fast front transients.
- Creepage distance Maintaining through frequent cleaning for the high voltage bushings.
- (GIS) equipment's periodic preventive maintenance.

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**Energy Storage and its impact on Grid Stability**

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- Battery Storage and its effect on Grid Stability Case Study simulated with Digsilent Power Factory Study Case: Gas turbine Outage without BESS; Gas turbine Outage with BESS

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**Conclusion**

- This paper proposes BESS as a solution when performing as primary control in order to improve the system frequency after disturbance occurred, and to reduce the operating cost of other expensive power plants such as those which run on heavy fuel. Based on the results, BESS has shown a good performance in frequency control and can be used for emergency control purposes when the system load shedding is unavoidable.

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**Waste-to-Energy Future and Challenges in Jordan**

FICHTNER

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Waste and Its Energy Content
Waste Management and Waste Treatment Options
Thermal Treatment Technologies
Development of a Waste to Energy Project

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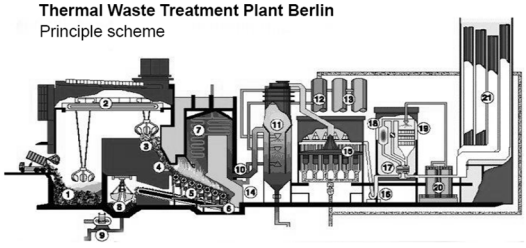
## Grate Furnace, Principle Scheme

**Thermal Waste Treatment Plant Berlin**
Principle scheme



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | waste bunker | 5 | roller grate with primary air | 9 | magnetic separator | 14 | water pump station |
| 2 | Cranes | 6 | wet slag extractor | 10 | flue gas duct | 15 | fabric filter |
| 3 | charging hopper | 7 | steam boiler | 11 | reaction zone | 16 | ID fan |
| 4 | pusher | 8 | slag bunker | 12 | silo (recirculat) | 17 | heat exchanger |
| | | | | 13 | lime silo | 18 | steam reheating |
| | | | | | | 19 | DeNOx system (SCR) |
| | | | | | | 20 | ammonia storage tank |
| | | | | | | 21 | stack |

Main supplier for Berlin plant : Babcock Borsig Berlin (grate, boiler), ABB (flue gas treatment)
Deutsche Babcock Anlagen (DeNOx), AEG (electrical & control systems)

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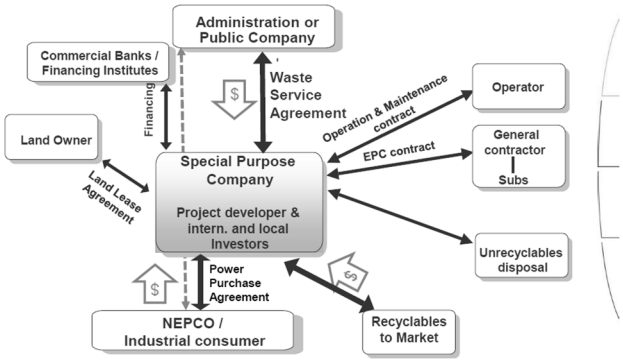
## Public Private Partnership – Waste Management

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**Digital Substation, FACTS and effects on Renewable Penetration**

ABB

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- Solar Power
- Jordan Power Generation
- Integration of renewables into the grid
- Major Types of Grid Integration
- FACTS Solution for Renewables
- Small Grid Concept
- Digital Substation

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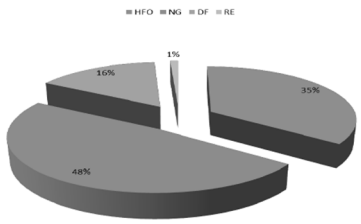
## Jordan Power Generation

Power Generation as of 2017




Peak Load 35 00MW

Installed Capacity: 3900 MW

| | |
|---|---|
| Households | 43% |
| Industry | 25% |
| Commercial | 15% |
| Water Pumping | 15% |
| Street Lighting | 2% |

- Solar energy: high solar intensity (5-7 kW/m²-day) and 3000 hrs per year
- Good wind speeds (6-8 m/s) in different regions, estimated potential of 1000 GWh

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## ntegration of renewables into the grid

lew challenges require a transition to a smarter grid

| | Challenges | ABB solution |
|---|---|---|
|  | **Remote bulk generation**<br>Areas with the best solar resources are often situated in remote locations. Tapping into these resources will require efficient ways to transport energy over long distances. | Substations<br>HVDC<br>FACTS<br>BESS<br>Ventyx software solutions |
|  | **Distributed generation**<br>Power generation is now commonly found on the distribution level such as residential and commercial PV installations. Increasing levels of distribution level generation will require new approaches to regulate and manage this energy. | BESS<br>Ventyx software solutions<br>Active voltage regulation |
|  | **Volatile generation**<br>With increasing levels of renewable energies on the grid, power production is increasingly volatile. Taking advantage of high penetration of renewable energies will require grid stabilization and more efficient ways to cope with volatility. | BESS<br>Ventyx software solutions |

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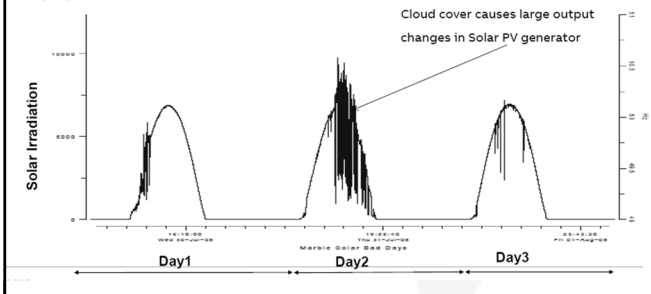
## Renewable Energy Integration Challenges

Managing Power Output Fluctuations - PV

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**Digital Substation**

**Thanks to new technologies, the advantages are obvious:**

Advantages:

• Up to 50% less OPEX for operation and maintenance of a substation thanks to End-toend integration of monitoring and diagnostics

• Up to 50% smaller foot-print thanks to sensors and integration of functions

• Substitution of up to 80% of signaling wires

• Linear NCIT and tools for up to 40% shorter cycle times

• Smaller or no control room

• Safety for personnel during operation and maintenance

• Cyber hardened

• Flexible, future proof

• Provides all necessary data and information for a stable and reliable operation of the grid given the new constraints

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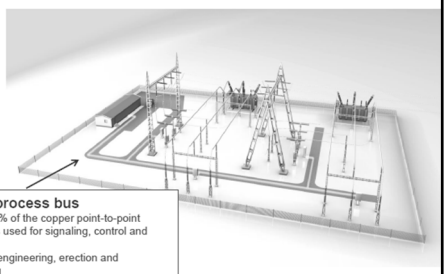
**Digital Substation**

The process bus IEC61850-9-2

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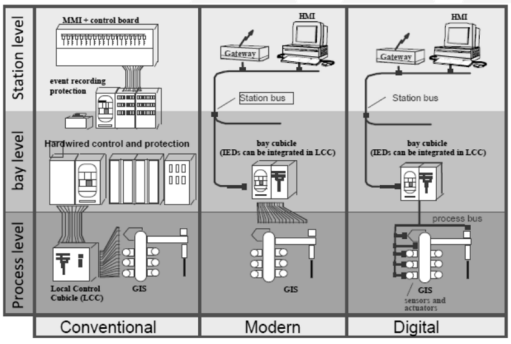
• **Digital Substation** IEC 61850 Bus substitutes copper signaling wires




The standard IEC 61850-9-2 Process bus is introduced by digital substations

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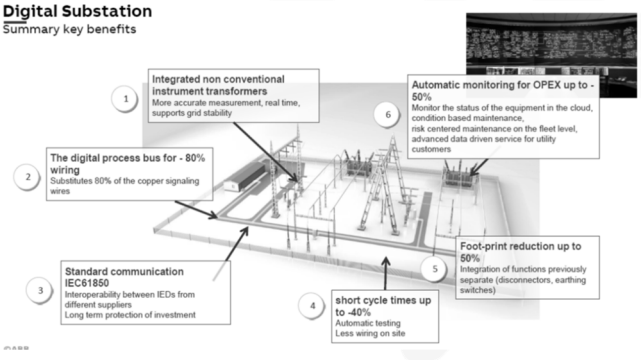
**Digital Substation**

Summary key benefits

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**Case Study on Mechanical Depressurization of Live Transformer Subject to Internal Arc**

**SERGI TRANSFORMER PROTECTOR**

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## Incident Details

**Serious internal fault in a step-up transformer at a Hydro Power Plant in Russia on May 3, 2013**

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## Incident Details: The Transformer

Power Rating:
400 MVA
Voltage:
525/15.75kV
Year Manufactured:
2008
Size:
~9x4x8m
Oil Weight:
82 tons
Total Weight:
292 tons

## Incident Details: Safety Protections on Transformer

Multiple Safety Protections:

- Routine DGA gas analysis and Buchholtz
- [illegible]
- [illegible]
- [illegible]
- [illegible]

- Focus on the role of the mechanical depressurization safety devices
- Use simulation results to interpret the incident outcome

*Also:*

- Transformer was not old (in operation 1 year)
- Transformer was not overloaded (was operating at 360 MVA)

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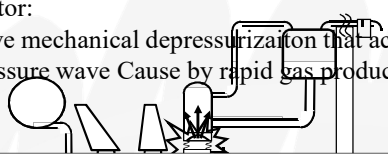
## Sergi Transformer Protector Device

Operating Principle of the SERGI Transformer Protector:

Passive mechanical depressurizaiton that activates by pressure wave Cause by rapid gas production of arc



- Not intended to act for slow gas releases of thermal fault
- Not resealable
- Intended for fast evacuation of oil and gas on millisecond timescale

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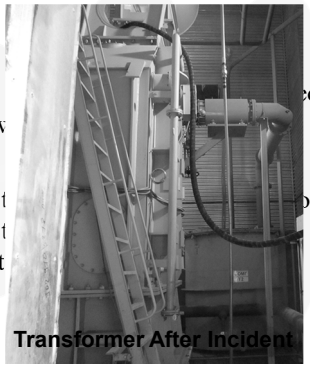
## Incident Details

Transformer [illegible] dance short-circuit fault v[illegible]

Ultimately, t[illegible] significant damages to t[illegible] surrounding equipment at [illegible]



Transformer After Incident

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## Incident Details: Location of Fault

- Significant scorching
- Approximately 1m length
- Fault at HV Phase B

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## Conclusions

- During a 6.586 MJ internal fault, multiple safety protections were actuated in a 400MVA transformer, including mechanical depressurization devices.
- No permanent tank deformation was found, the transformer was returned to service
- Based on its early time of actuation, and confirmed using fluid modeling, the SERGI Transformer Protector reduced the internal pressure and saved the transformer from explosion and fire.
- Based on FSI simulations, higher stresses could develop near the high voltage bushings.
- To mitigate higher arc energy events, protection of oil bushing cable boxes is recommended.

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**Enefit – Waste to Energy Solutions**

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Waste to Energy - Estonian Case

## Iru CHP and Waste-to-Energy

**Iru CHP built in 1974-1982**

- 2 hot water boilers 116 MWth, 3rd 16 MWth boiler installed in 1990
- Originally natural gas and fuel oil used as fuel

**New Waste-to-Energy unit constructed 2010-2013**

- Installed electrical capacity 17 MW
- Thermal capacity 50 MW
- Electricity and thermal energy from municipal waste, natural gas and liquid fuels.
- Provides thermal energy for Tallinn and Maardu, 1/3 of total thermal energy
- Uses 250 000 tons of municipal waste annually

Enefit

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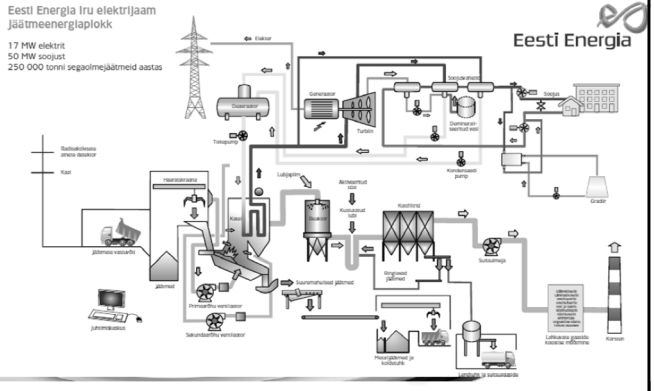
Eesti Energia Iru elektrijaam jäätmeenergiaplokk

17 MW elektrit
50 MW soojust
250 000 tonni segaolmejäätmeid aastas

Eesti Energia



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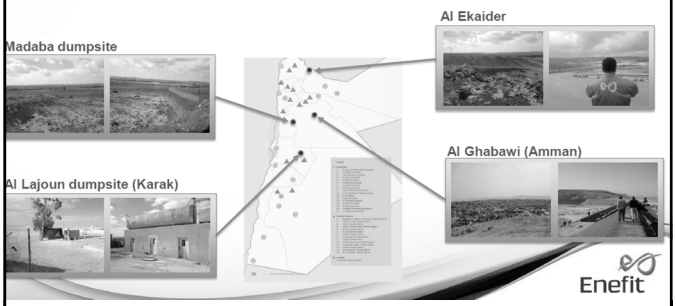
Enefit and WtE in Jordan

## Example of sites investigated by Enefit

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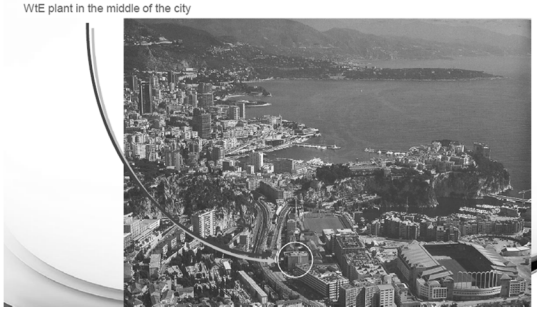
## Monaco WtE

WtE plant in the middle of the city



Enefit

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**Long Term Performance Of Pad-mounted Substation With Natural Ester FR3 Dielectric Fluid**

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**Why Natural Ester fluid?**

Natural Ester is the new technology in the transformer oil made from natural resources.

Environmental safety:

- Biodegradability: Natural Ester test and classified as EPA classification as (ultimately Biodegradability) or (readily Biodegradability).
- Toxicity with zero trout mortality through standard test.

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- Natural Ester are classified under Edible oil regulatory.
- The fluid can be rejuvenated, recycle and readily disposed.
- Fire Safety:
- Natural Ester fluid has a high fire point (360° C).
- It is less flammable dielectric coolant.
- Natural Ester (FR3) decrease or eliminate the dangers and cost of the fire caused by the mineral oil transformers.

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Natural Ester fluid properties

- Natural Ester dielectric fluid is (IEC 60076:2013 part 14) :
- Natural Ester can make the transformer to operate at 20 degree warmer than the mineral oil at the same condition.
- Extend the load capacity by 20%.
- Extend the life cycle of the asset by 5-8x more than mineral oil.
- Lower maintenance cost.
- Extend the loss of CO2 by 56x than mineral oil.
- Its produce from renewable resource so it production and utilization is simple and cost effective.

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## Case Study

- In this paper we discuss the case study of METALEC Manufactured pad-mounted distribution transformer.

| Specifications | |
|---|---|
| Rated Power | 630 KVA |
| Ratio | 11 / 0.415 KV |
| Dielectric fluid | FR3 |
| Manufacture year | 2005 |
| Switchgear capacity | 16KA |

- Pad-Mounted was delivered with tamper-resistance housing to prevent access by unauthorized persons.
- The transformer work for more than 10 years with high load capacity.

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**Conclusion**

- It may represent a new paradigm for distribution transformer.
- JEPCO want to moving ahead in using the Natural Ester (FR3) technology in power and distribution transformer.
- The capacity of holding much high value of overloading improve the range of the application of the transformer, allow increase the average load, and higher peak load will not affect the transformer.
- Reduction of the cellulose ageing of the insulation paper.
- May represent an opportunity for utility to achieve real finical saving in the power and distribution network.

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**Impact of Renewable Energy Tariff Policies on Tariff Structure**

88

**Electricity tariff in Jordan**

- Electricity tariff in Jordan is divided according to usage objective and quantity of consumption, in order to balance the various economic sectors.
- Tariff sectors mainly divided to:
- Household
- Regular
- Commercial
- Industrial
- Agriculture
- Water Pumping

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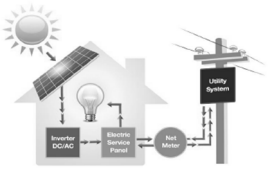
**Net-Metering Tariff (NEM)**

- Net energy metering (NEM), is a metering and billing arrangement designed to compensate distributed energy generation (DG) system owners for any generation that is exported to the utility grid.
- The utility customer pays for the net energy consumed from the utility grid




**Feasibility of Net-Metering in Jordan**

- The feasibility of installing solar energy using Net-Metering system mainly based on the average tariff.
- We can calculate the feasibility based on the supposed prices of renewable energy systems and the average tariff:
- cost of 1KWp PV = 900 JD.
- Project Life 20 Year.
- Annual generation =1560 KWh/KWp.
- electricity tariff = Avg. tariff.

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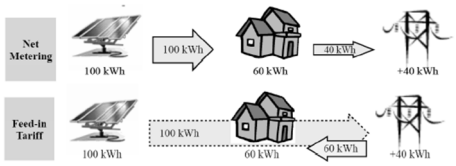
**Feed-In tariff**

- A Feed-in-Tariff (FIT) is an instrument for promoting generation of electricity from renewable energy sources. A Feed-in-Tariff allows power producers to sell renewable energy generated electricity to an Off-taker at a pre-determined tariff for a given period of time.

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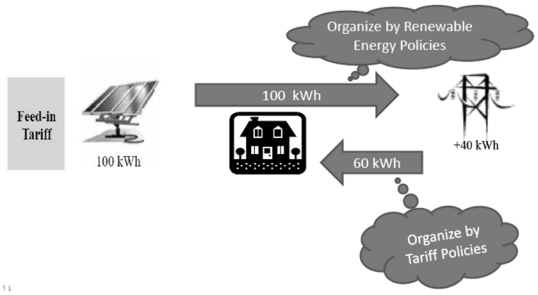
## Feed-In tariff VS Net-Metering

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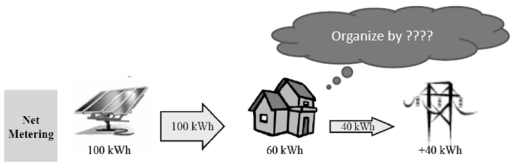
## Feed-In tariff VS Net-Metering

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### Conclusions

- The net metering system will lead us to problems in tariff structure and in the financial structure of distribution companies.
- Feed-in Tariff system can be better able to manage and control the renewable energy sector.
- Feed-In allow everyone to invest in the future energy either in small, medium or large investment projects.

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**Electricity generation from animals manure: A case study on Bio –Methane power plant in Al- Dhlail**

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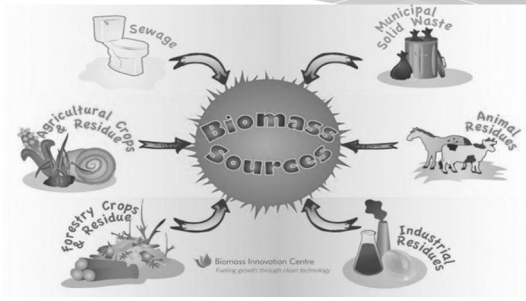
- Jordan has a substantial biomass resources formed in a solid wastes, sewage, industrial wastes and animal manure

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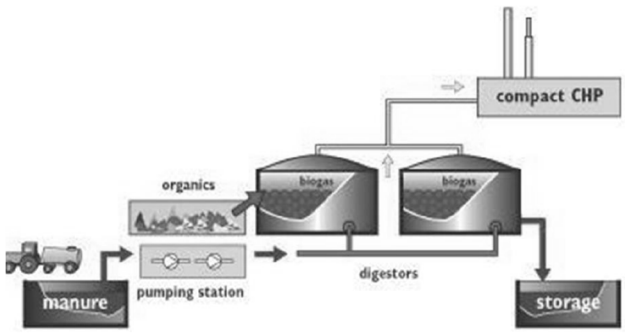


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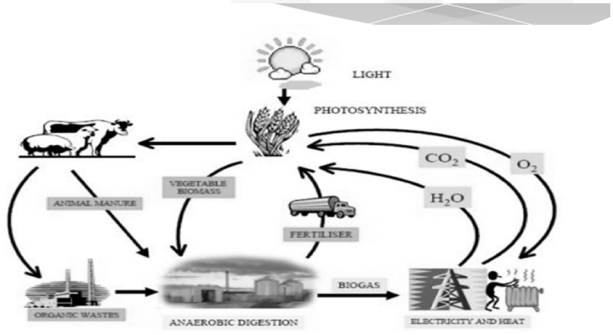
- Uses Of Methane

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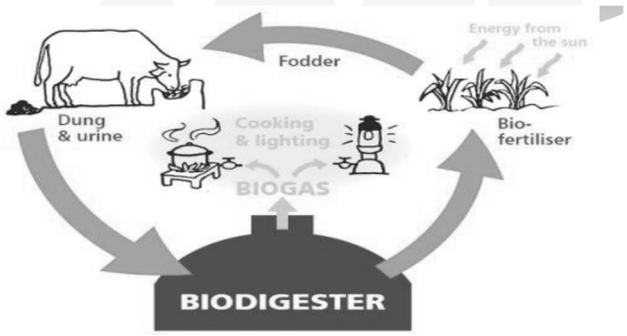
- The bio gas " Methane " can be used as cooking gas, fuel for vehicles, operate electricity turbines, and so on …



**Conclusion**

In Dhlail the electricity which generate from the bio methane power plant can be used for small use such as lightning, heating and operating the water pump.

2.Bio methane is one of the renewable energy sources especially in the areas which have a huge amount of bio waste.

3.The process reduces water pollution and emission of greenhouse gas effect.

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