SOLAR
ENERGY
TECHNOLOGY

Introduction Solar Photovoltaic Systems

Gerrit Jacobs

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Jakarta
Indonesia

Introduction

What will be discussed:

- Introductions
- PV system arrangements
- Units of measurement and basic formula
- The client
- Meeting the needs of the client
- PV system components
- PV process and construction of modules
- Batteries
- Charge regulators
- Loads and inverters

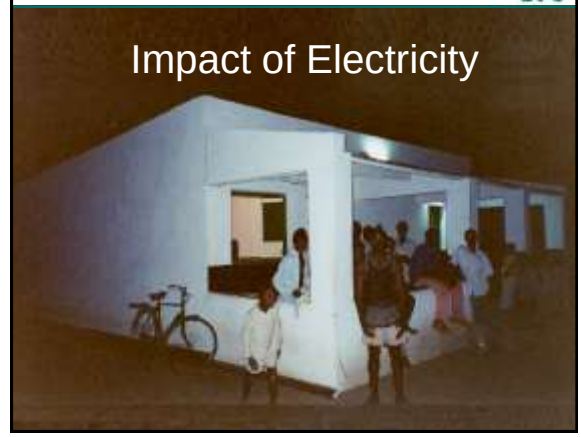
Introduction

Duties of a solar entrepreneur

1. Evaluate the energy needs of the client
2. Determine the appropriate size of the solar system
3. Estimate the prices of such systems
4. Select and purchase quality components
5. Ensure the marketing of solar systems as well as other services for the clients
6. Install maintain and repair the solar system
7. Inform and advice current and future solar system users

Introduction

Impact of Electricity



Introduction

Electricity plays an important role

After Before

Photo: Jon Exel

Introduction

WARNING!

– Photovoltaic modules can be short-circuited without damage. However, a short circuit in other system components or sparks may cause component damage and dangerous, even lethal, conditions. This is particularly true for storage batteries.

– **Never short-circuit batteries!**

PV system arrangements

PV Technologies for Rural Electrification

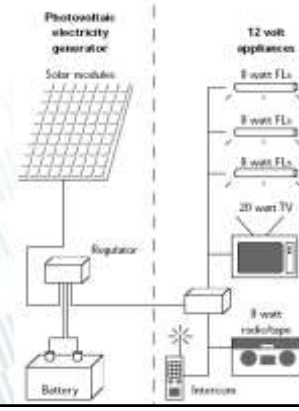
- Solar Lantern — DC
- Solar Home System — AC
- PV Battery Charging Station

- PV Mini-grid — Hybrid Systems
  - PV - Diesel engine
  - PV - Windmill

7

PV system arrangements

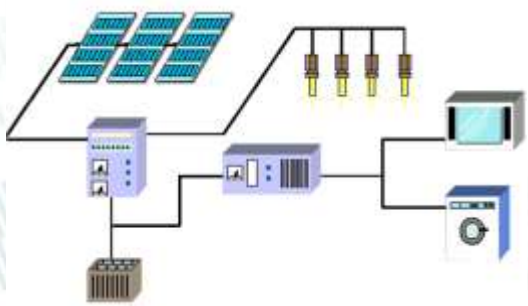
12V DC System



8

PV system arrangements

AC System



9

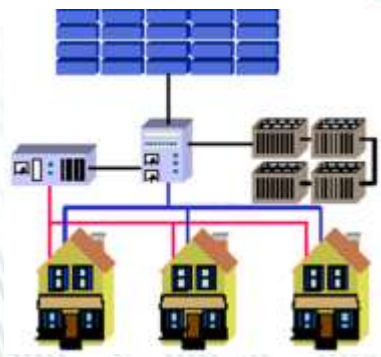
PV system arrangements

Stand-alone Solar Systems

10

PV system arrangements

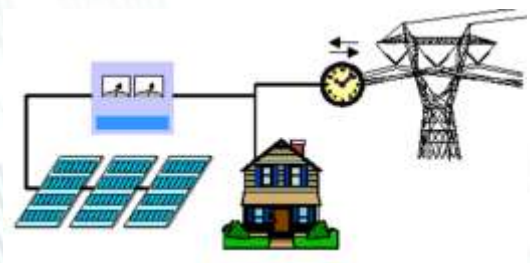
Minigrid System



11

PV system arrangements

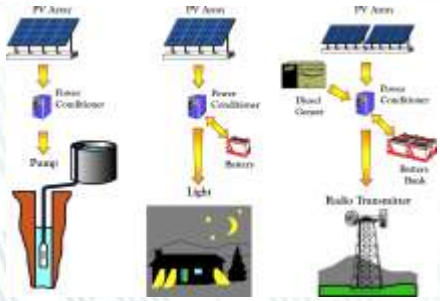
Grid Connected System



12

PV system arrangements

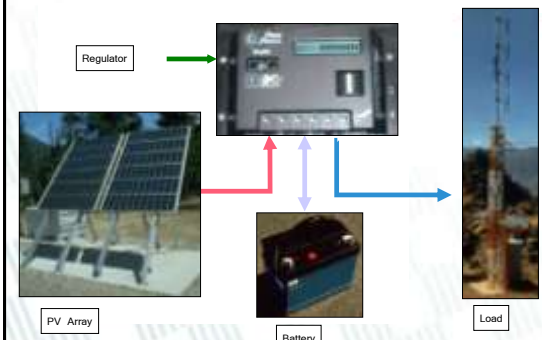
Types of Stand-Alone PV Systems



13

PV system arrangements

System for Communication



14

Units of measure and basic formulas

Back to the Basics

- **Energy**: ability to do work (J or Wh)
- **Electric power**: rate at which energy is consumed or supplied
- **Irradiation**: Solar radiation per square metre (W/m^2)

15

Units of measure and basic formulas

Units and Formulas

Unit	Symbol	Measure	Symbol	Expressed in other units
Time	t	Second	S	----
Voltage	V	Volt	V	P / I
Current	I	Ampere	A	P / V
Power	P	Watt	W	V x I
Energy	E	Watt-hour	Wh or J	W x t
Battery capacity	Q	Ampere-hours	Ah	I x t; E / V
Irradiation	Irr	Watt per square metre	W/m^2	----
Lumen	lm	Flow of light	----	----
Lux	lx	Illumination	lm/m^2	----

Formula	Symbols
Power = Voltage x Current	P = V x I
Power = Current x Current x Resistance	$P = I^2 \times R$
Energy = Power x Time	E = P x t
Energy = Battery capacity x Voltage	E = Q x V
Resistance = Voltage / Current	R = V / I

16

The client

Adding up to succes

17

The client

It is important to:

Meeting the needs of the client

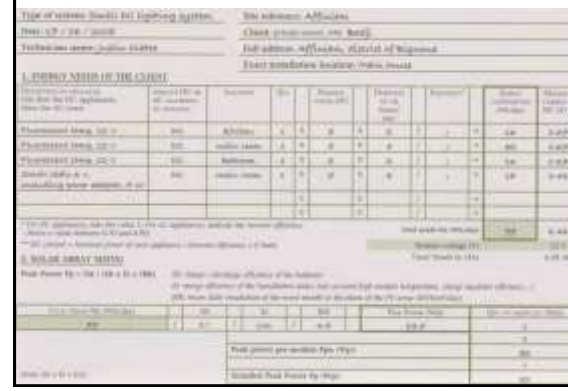
Appliances

	Appliance	Typical power consumption (Watts)	Typical daily use (hours/day)	Typical daily consumption (Wh/day)
Common appliance s in SHS	Light bulb	5–15	1–4	5–60
	Radio	5	1–10	5–50
	Radio cassette player	10	1–5	10–50
	B/W television	35	1–5	35–175
Possible appliances in SHSs	Small fan	5	3–6	15–30
	Battery charger	2	2–10	4–20
	Mobile phone charger	5	0–1	0–5
	Stereo installation	20	1–4	20–80
	Radio transmitters	stand-by: 5 transmit: 300	0–2 0–0.5	0– 10 0–150
	Video recorder	70	1–3	70–210
	Lap-top	40	1–6	40–240
Appliances only for larger PV systems or alternatives	Blender	300	0.1–1	20–300
	Sewing machine	150	1–3	150–450
	Small refrigerator	70	24	1,680
	Water pump	200	4-10	800–2,000
	Electrical drill	600	1–3	600–1,800
	Electrical iron	600	1–3	600–1,800
	Electrical cooking plate	1,000	0.5–3	500–3,000
	14' colour TV	80	1-4	80–320

19

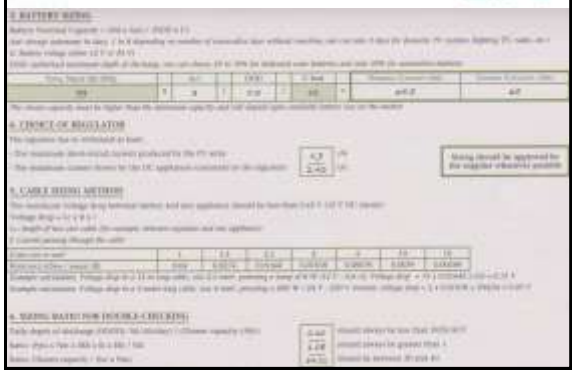
Meeting the needs of the client

Sizing of a DC Solar System (1)



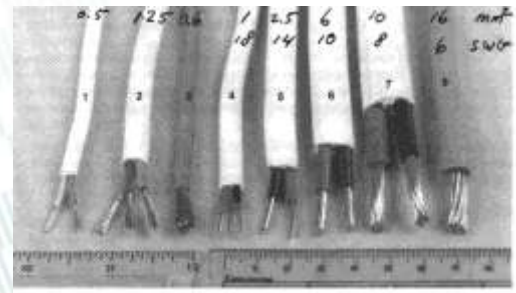
Meeting the needs of the client

Sizing of a DC Solar System (2)



Meeting the needs of the client

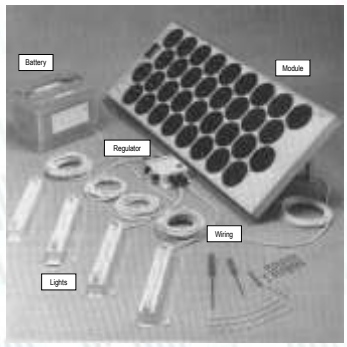
Different Cable Sizes



22

PV system components

Solar Home System



23

PV system components

Components of a small SHS


Solar Module (Panel)


Battery


Regulator

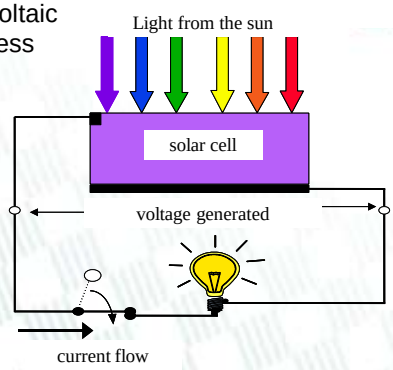

Lights


Cables

24

PV process and construction of modules

Photovoltaic Process

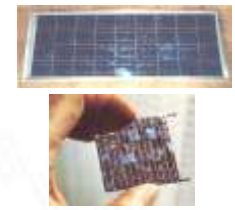


25

PV process and construction of modules

PV Cell Types

mono-crystalline



multi-crystalline

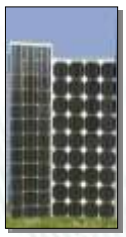
Solar cell efficiency:

$$\eta\,\% = \frac{\text{generated energy}}{\text{incident energy}} \times 100$$

26

PV process and construction of modules

PV Cell Types



Silicon Monocrystalline

- 14% to 16% efficiency

CIS thin film

- 12% efficiency
- unifirm colour

27

PV process and construction of modules

Characteristics of a PV Module

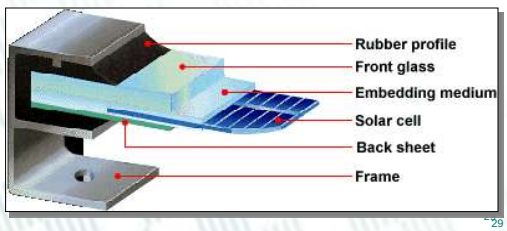
- One solar cell produces approximately 0.5V DC
- Normally 36 cells are connected in series
- Nominal voltage of the module is 12V DC
- The area of the solar cells determines the current

28

PV process and construction of modules

- Tempered glass with low iron content
- Embedding medium
- Solar cell
- Back sheet
- Aluminium frame
- Connection box

Construction of a PV Module



29

PV process and construction of modules

Quality Labels

TÜV Rheinland

CE

UL

JOINT RESEARCH CENTRE
ESTI – Ispra

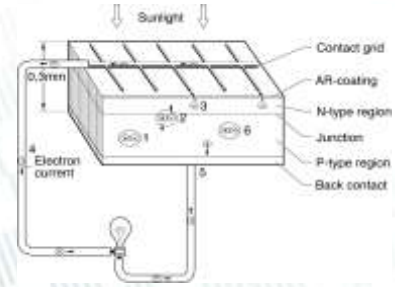
FM APPROVED

30

PV process and construction of modules

PV process and construction of modules

Photovoltaic Process

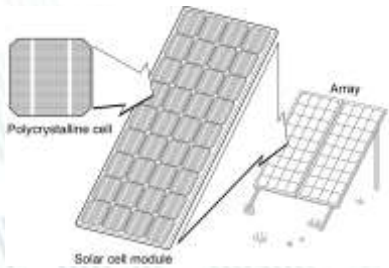


Mono-Crystalline, Poly-Crystalline and Amorphous silicon

32

PV process and construction of modules

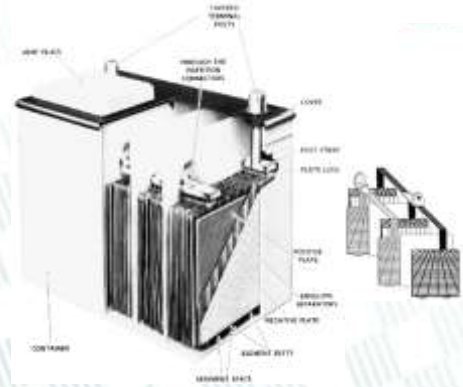
Cells, Modules and Arrays



33

Batteries

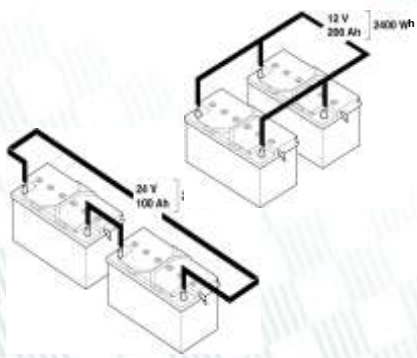
Construction of a Lead-Acid Battery



34

Batteries

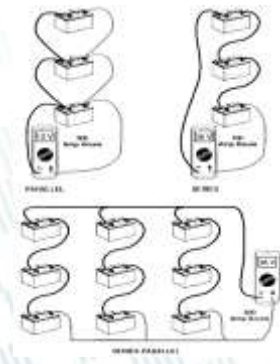
Battery Capacity



35

Batteries

Connecting Batteries



36

Batteries

Battery Connections

37

Batteries

Battery Connections

38

Batteries

Battery Connections

39

Batteries

Battery Connections

40

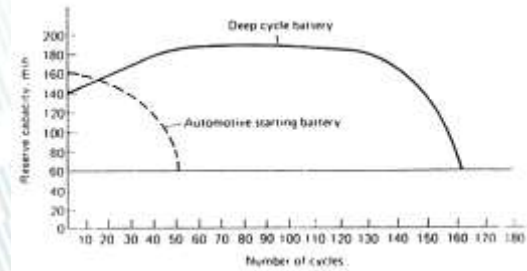
Batteries

The Reality ...

41

Batteries

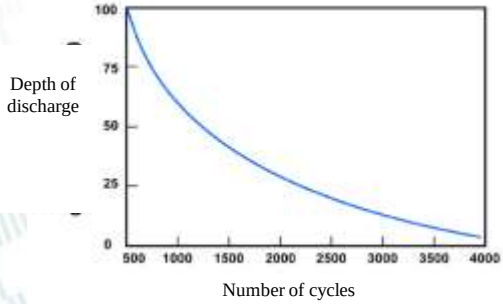
Automotive versus Deep Cycle Battery
(discharge rate = 25 A)



42

Batteries

Battery Life-time



43

Batteries

Battery Life-time

Type of plates	Car battery Thin plate	Vented "Solar" Thick plate	Sealed (gel) Thick plate	Stationary vented Tubular
User capacity	(25 to 200 Ah)	(30 to 200 Ah)	(25 to 150 Ah)	(150 to 2000 Ah)
DDOD 10%	3 to 4 years	5 to 7 years	6 to 8 years	> 10 years
DDOD 20%	2 to 3 years	4 to 5 years	5 to 6 years	10 years
DDOD 30%	1.5 to 2 years	3 to 4 years	4 to 5 years	6 years
DDOD 60%	6 months to 1 year	1 to 2 years	2 to 3 years	4 years
DDOD 80%	2 months	3 to 6 months	1 to 2 years	2 years

Type of Battery	Life span
Car Battery	3-12 months
Solar/Modified Car Battery	1-3 years
Sealed Battery	2-5 years
Deep Cycle Battery	4-8 years

Charge regulator

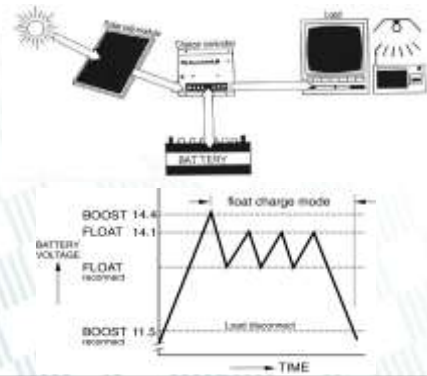
Regulator / Controller

- Indicates systems performance through LEDs and LCD screens
- Controls the module and load
- Minimises harm in case of short-circuit

45

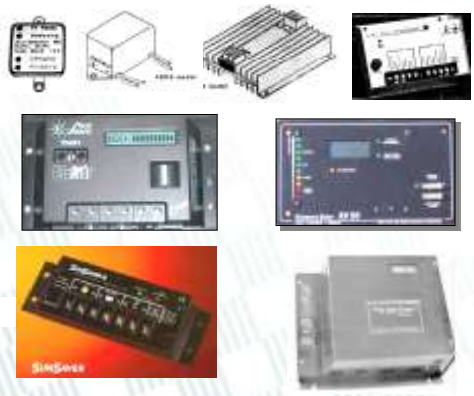
Charge regulator

Operation of the Regulator



46

Different Types of Regulators



47

Charge regulator

ProStar-30 Regulator

48

Charge regulator

Old Design Regulator

49

Charge regulator

Old Controller Technology

50

Charge regulator

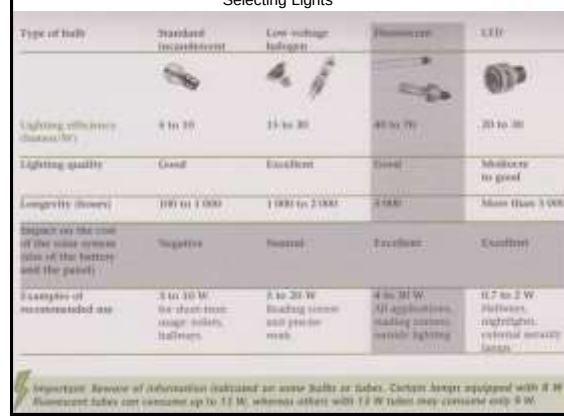
Controller - OutBack

- OutBack MX60
- 60A at 48V
- MPPT
- Efficiency of 98%
- Large digital display
- Datalogger of 64 days
- Fully programmable

51

Loads and inverters

Selecting Lights



Loads and inverters

Power Rating of Appliances

Appliance	Appliance Rating	Size of PV System		
		14W - 20W	50W	80W - 100W
Black & White TV (14")	20-30W	✓×	✓	✓
Color DC TV (14")	55-65W	×	✓×	✓
Color AC TV (14")	70-90W	×	×	✓
Color AC TV (21")	110W	×	×	✓×
VCR (Video)	20W	✓×	✓	✓
VCD/DVD player	20W	✓×	✓	✓
Radio (1 speaker)	5-10W	✓	✓	✓
Radio Cassette Player (1 speaker)	10-15W	✓	✓	✓

53

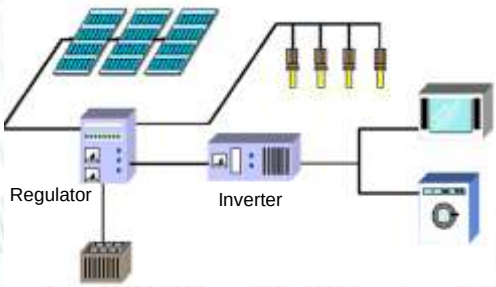
Loads and inverters

Appliance	Appliance Rating	Size of PV System		
		14W - 20W	50W	80W - 100W
Stereo system (2 speakers)	30-50W	×	✓	✓
Fridge	200-400W	×	×	×
Air Conditioner	1500W	×	×	×
Fan	60-100W	×	×	✓
Microwave	1000W	×	×	×
Desktop Computer	100W	×	×	✓×
Laptop Computer	40-60W	×	×	✓
Desk jet printer	60W	×	×	✓
Laser jet printer	1000W	×	×	×
Photocopier	1200W	×	×	×
Fax	20W	×	✓	✓
LCD Projector	200-300W	×	×	×
Iron	1000W	×	×	×
Room Light	3-6W	✓	✓	✓
Reading/Security Light	10-18W	✓	✓	✓
Mobile Phone charger	5W	✓	✓	✓
2-way radio charger	5-10W	✓	✓	✓
Sewing Machine	75W	×	×	✓
Electric Hair Cutter	15-25W	✓×	✓	✓
Decoder	20-30W	×	✓	✓

54

Loads and inverters

Connecting Inverters



Inverter connected to the regulator

55

Loads and inverters

Different Types of Inverters (1)

56

Loads and inverters

Different Types of Inverters (2)

57

Loads and inverters

Installation using OutBack Inverters

58

Loads and inverters

Testing of Inverter

59

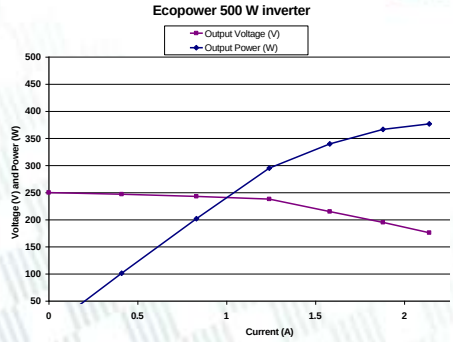
Loads and inverters

Inverter Output Signal

60

Loads and inverters

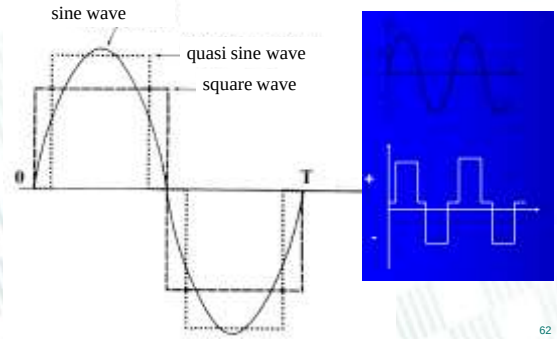
Performance of Inverters



61

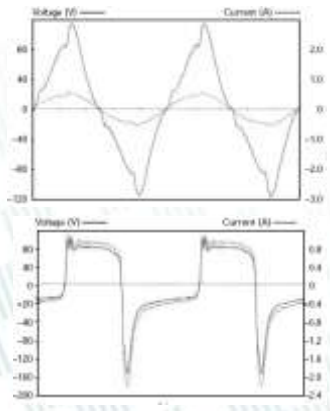
Loads and inverters

Output Voltages of Inverters



62

Loads and inverters

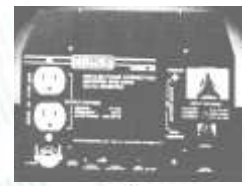


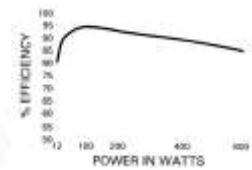
Output Voltages and Currents of Inverters

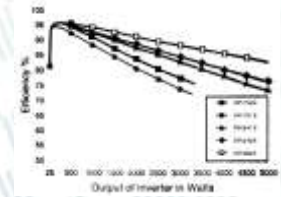
63

Loads and inverters

Characteristics of Inverters

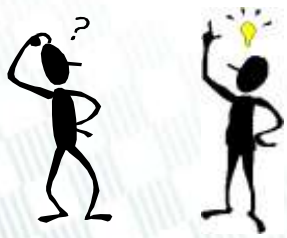






64

QUESTIONS ?



Gerrit Jacobs
ETC Energy

winter@etcnl.nl
PO Box 64
3830 AB Leusden
the Netherlands
T: +31 33 432 6025
F: +31 33 494 0791

65