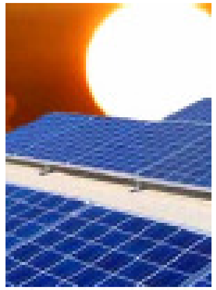

Sustainable Development. Integrated Renewable Energy Systems – Holistic Modelling & Control.

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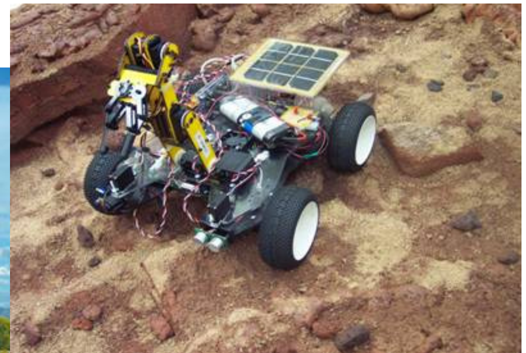
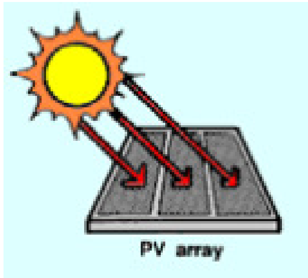
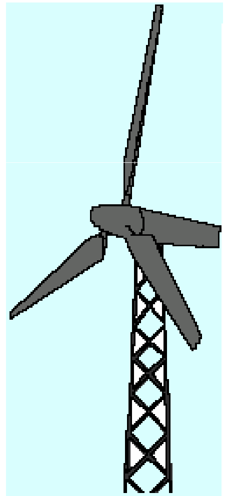


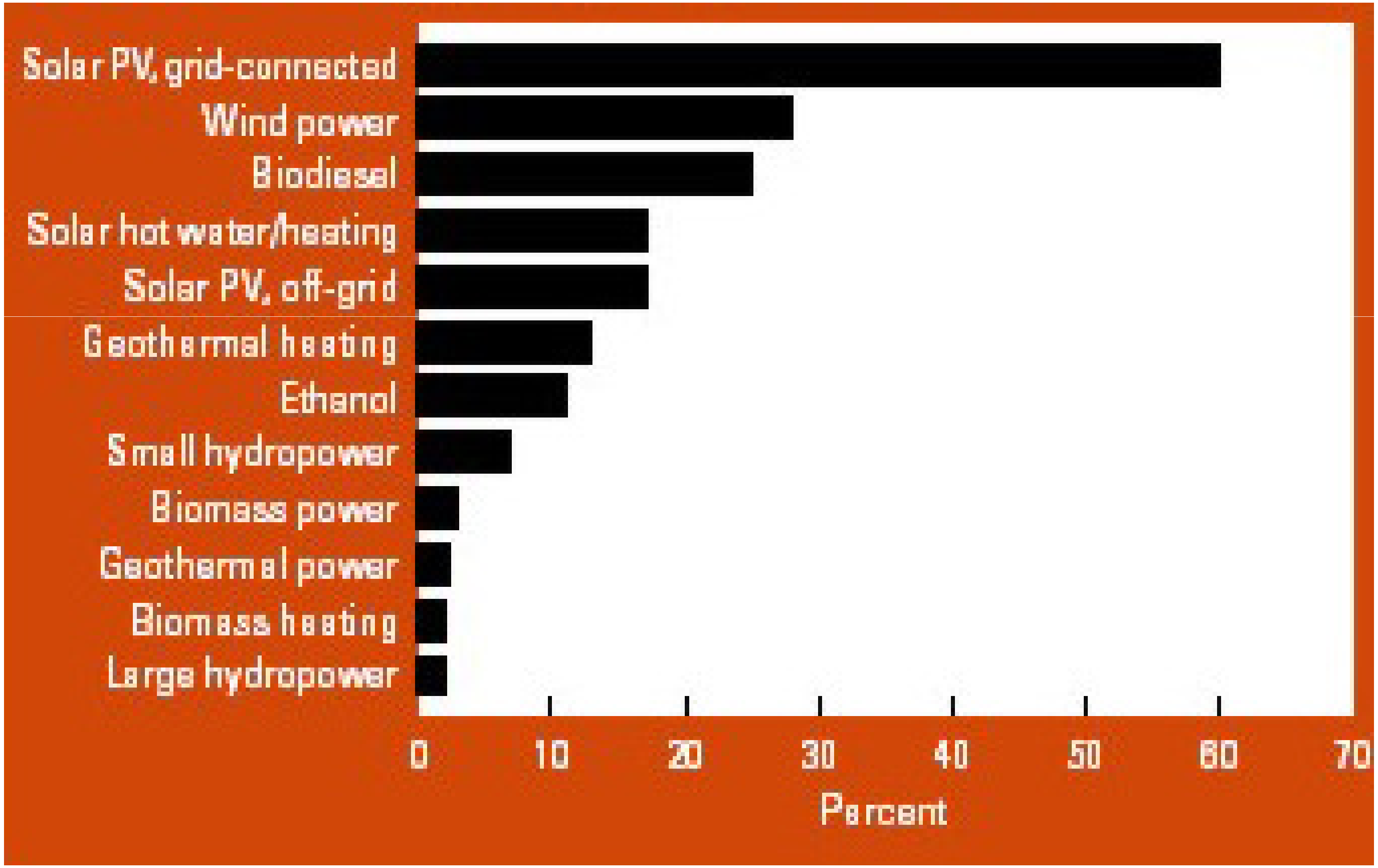
RENEWABLE ENERGY TECHNOLOGIES

- *Solar energy*
  - ➢ *Photovoltaic*
  - ➢ *Thermal*
- *Wind energy*
- *Bioenergy*
- *Hydro energy*
- *Ocean Wave Energy*





Average annual growth rates of renewable energy capacity, 2000- 2004



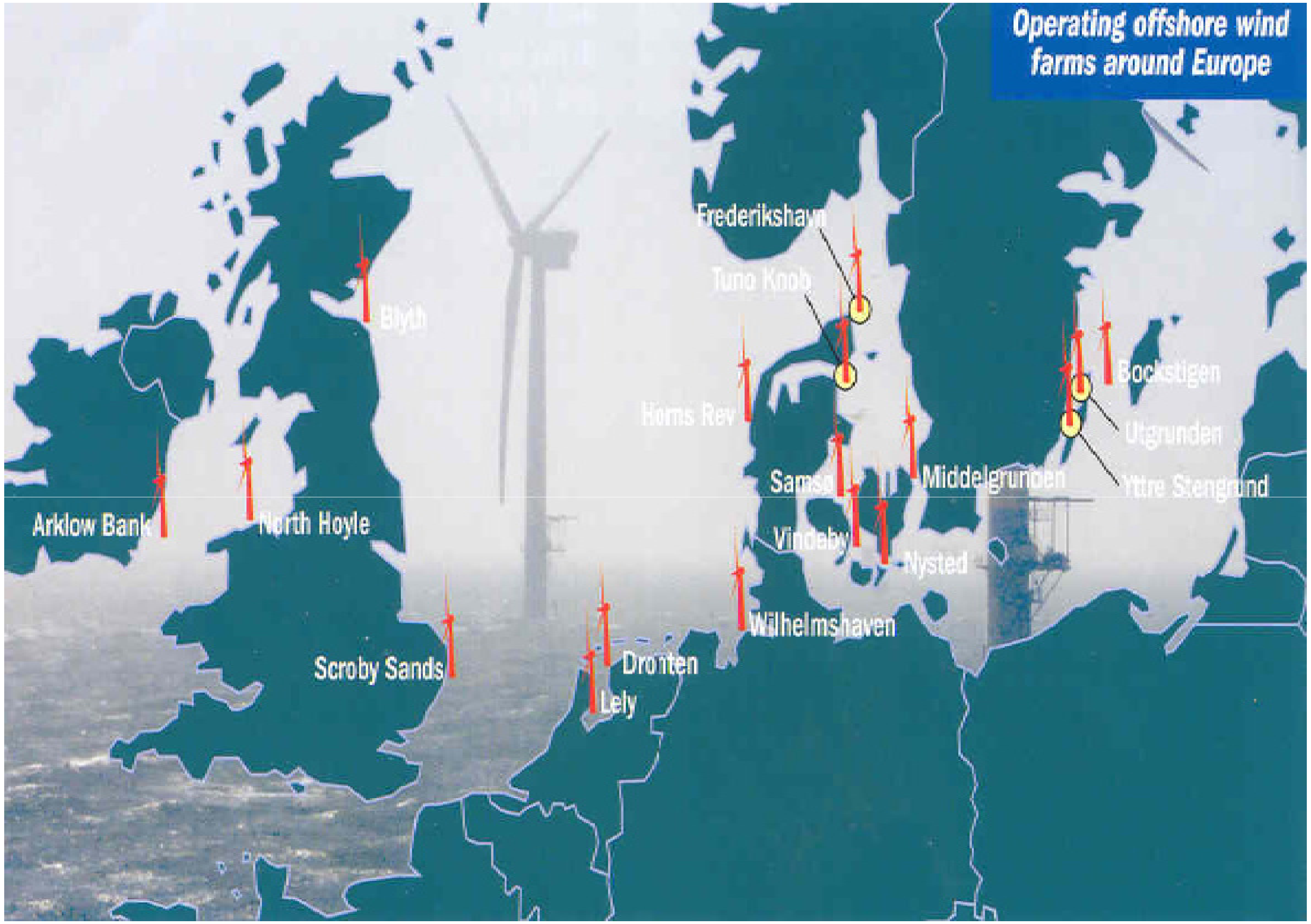
Photovoltaics

- Why Photovoltaics and not Wind or hydro?

  Users of solar PV and solar thermal systems require very little training, as the systems are largely automatic: this is one of the major **benefits** of solar systems **compared** with **other renewable** energy supplies.

Wind energy

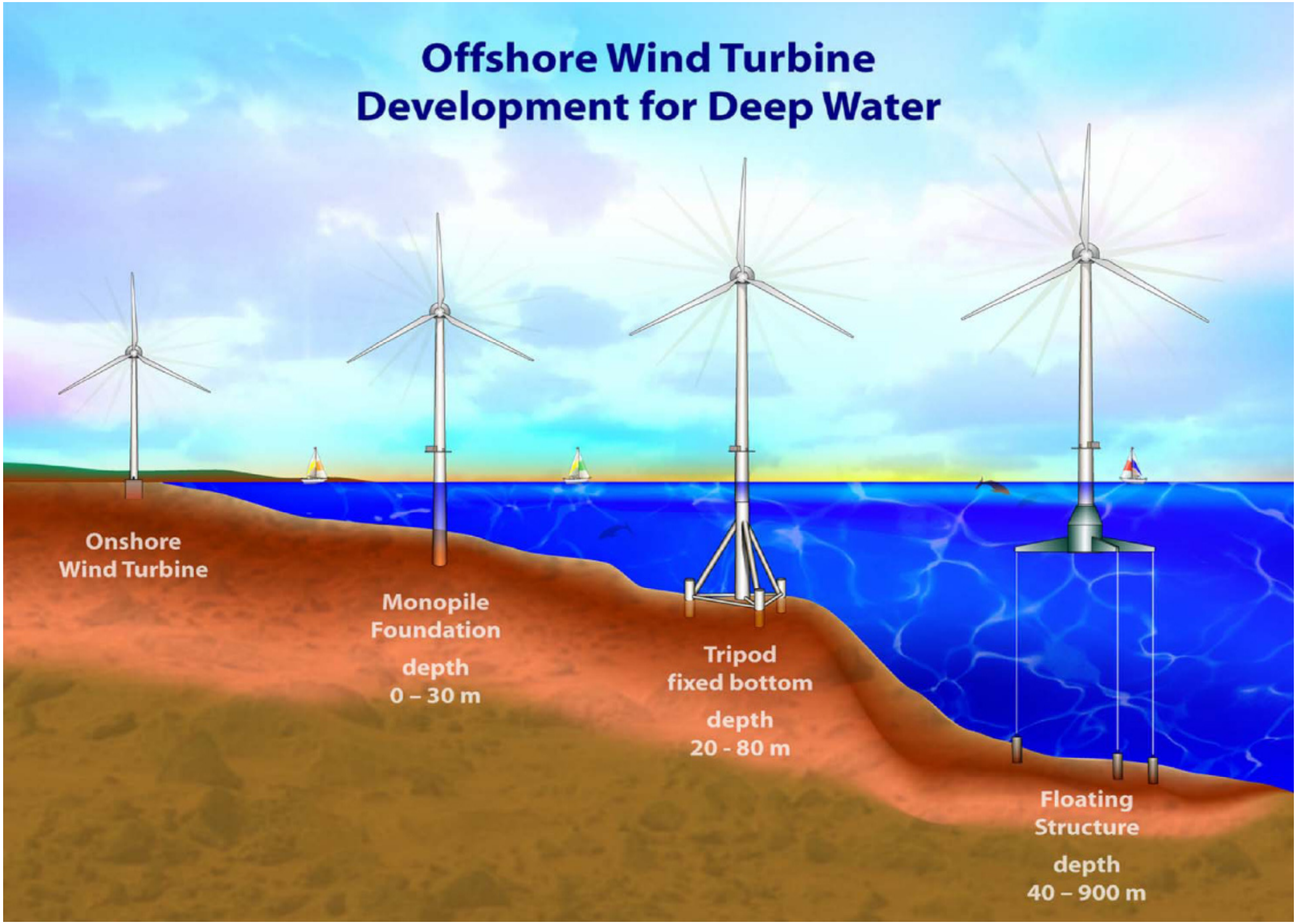
- Onshore wind power generation is now considered cost competitive with most other forms of generation. The costs are more favorable for large-scale installations.
- Offshore wind power is still considerably more expensive but costs are falling with the deployment of more effective specialized resources for installing the turbines and cables.
- For reasons of output power quality and to avoid excessive operational stresses, large wind turbines usually include frequency conversion systems to permit variable-speed operation.
- The major disadvantage of wind energy is its intermittency leading to costs associated with spinning reserve elsewhere on the utility grid or to the need for energy storage which is at present not developed on a sufficient scale. If these costs are included then wind power can appear rather more expensive.

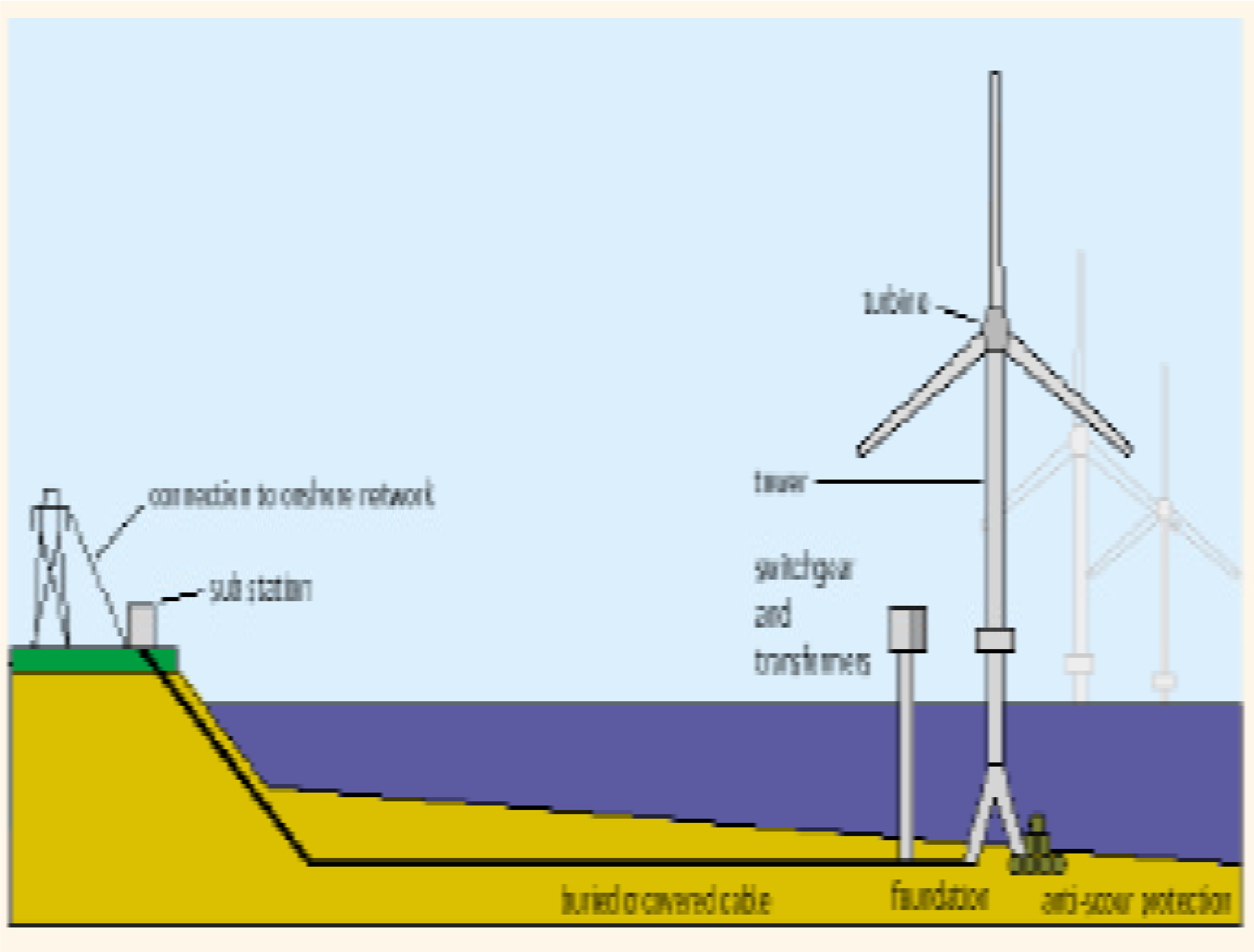


Sweden 3%
Netherlands 2%
Ireland 3%
Germany 1%
Denmark 53%
United Kingdom 38%
804-MW Installed Dec 2005

Location of Existing Offshore Installations Worldwide

Source: Wind Directions, September 2004


Offshore Wind Turbine
Development for Deep Water
Onshore
Wind Turbine
Monopile
Foundation
depth
0 – 30 m
Tripod
fixed bottom
depth
20 - 80 m
Floating
Structure
depth
40 – 900 m


connection to onshore network
sub station
turbine
tower
switchgear
and
transformers
buried or covered cable
foundation
anti-scour protection

Horns Rev Wind Farm - Denmark

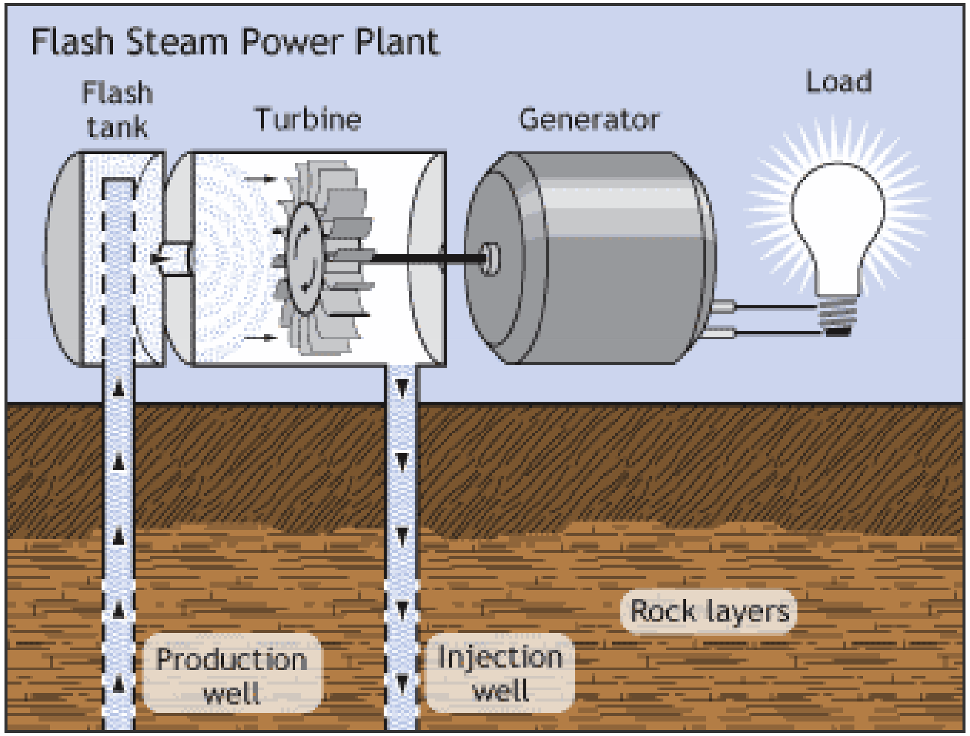
- **Country:** Denmark
- **Location:** West Coast
- **Total Capacity:** 160 MW
- **Number of Turbines:** 80
- **Distance to Shore:** 14-20 km
- **Depth:** 6-12 m
- **Capital Costs:** 270 million Euro
- **Manufacturer:** Vestas
- **Total Capacity:** 2 MW
- **Turbine-type:** V80 - 80m diameter
- **Hub-height:** 70-m
- **Mean Windspeed:** 9.7 m/s
- **Annual Energy output:** 600 GWh

Bioenergy

- Biofuels - extracted from crops like rapeseed can be used to supplement or replace engine fuels
- Geothermal
- Energy from waste-products such as agricultural slurry, sewage, waste fats and oils and gases released from landfill sites are all alternatives which would benefit the environment
- Gasification-is a process which releases gas from wood that can then drive an engine to produce electricity. The wood is 'burned' in such a way as to keep harmful emissions to a minimum and of course any CO2 released is balanced by that which the plant absorbed during growth. The process has been used in Sweden for many years and is the subject of ongoing trials in Northern Ireland.

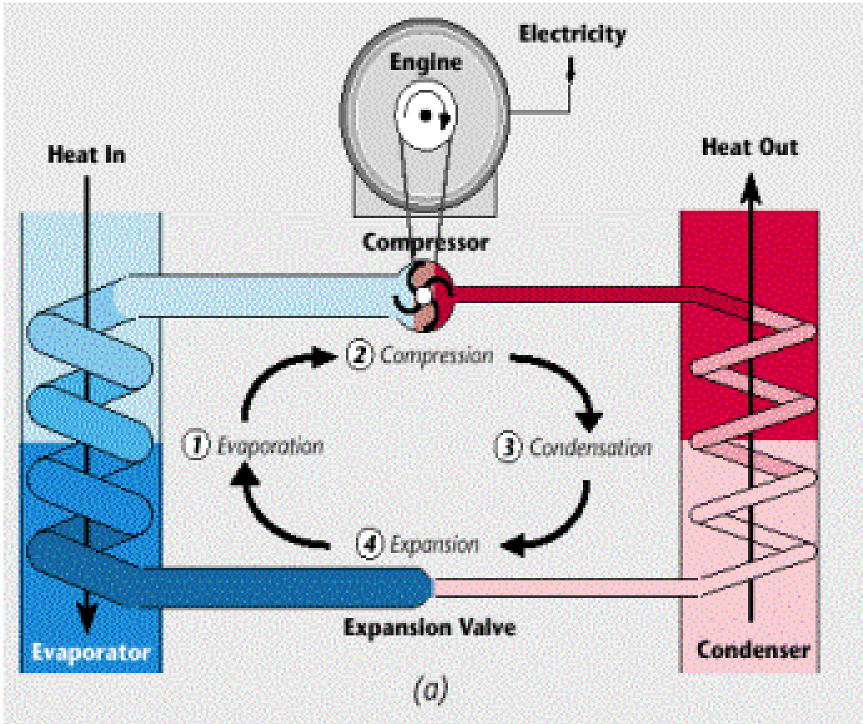
Geothermal energy

- Hydrothermal fluids above 360°F (182°C) can be used in flash plants to make electricity. Fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or "flash." The vapor then drives a turbine, which drives a generator. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy
- http://www.youtube.com/watch?v=rfUQy86ZMpQ&eurl=http%3A%2F%2Fhome%2Eclara%2Enet%2Fdarvill%2Faltenerg%2Fgeothermal%2Ehtm&feature=player_embedded



HEAT PUMP

- A heat pump is basically an air conditioner with a valve that allows it to operate in reverse. A heat pump is an electrically-powered device that extracts available heat from one area (the heat source) and transfers it to another (the heat sink) to either heat or cool an interior space or to extract heat energy from a fluid. In the case of a fridge, for example, heat is transferred from the interior of the fridge to the condenser coils at the exterior



Types of heat pump

- The two main types of heat pumps are compression heat pumps and absorbtion heat pumps. Compression heat pumps always operate on mechanical energy (through electricity), while absorption heat pumps may also run on heat as an energy source (through electricity or burnable fuels).
- A number of sources have been used for the heat source for heating private and communal buildings.
- Air source hear pump (extracts heat from outside air)
  - air–air heat pump (transfers heat to inside air)
  - air–water heat pump (transfers heat to a tank of water)
- Geotermal heat pump (extracts heat from the ground or similar sources)
  - geothermal–air heat pump (transfers heat to inside air)
    - ground–air heat pump (ground as a source of heat)
    - rock–air heat pump (rock as a source of heat)
    - water–air heat pump (body of water as a source of heat)
  - geothermal–water heat pump (transfers heat to a tank of water)
    - ground–water heat pump (ground as a source of heat)
    - rock–water heat pump (rock as a source of heat)
    - water–water heat pump (body of water as a source of heat)

Second law of thermodynamics

- Heat generally cannot flow from a material spontaneously at lower temperature to a material at higher temperature.(Clausius statement)
- For example in a refrigerator, heat flows from cold to hot, but only when aided by an external agent (i.e. the compressor).

In secolul al- XIX - lea, fizicianul J. Watt a descoperit ca **un gaz care este comprimat degaja caldura si invers, daca este destins - absoarbe caldura!**

Acest fenomen este regasit in functionarea pompei de caldura (PDC).

In timpul functionarii PDC exista:

-un corp cu temperatura mai joasa (de exemplu temperatura mediului ambiant - aer, apa, sol) pe care il vom numi **sursa rece** (si care ajunge in **vaporizator)**;

-un corp cu temperatura mai mica decit a sursei reci numit **agent frigorific** (acesta conform principiului enuntat poate prelua caldura sursei reci);

-un corp care va trebui sa primeasca , de la agentul frigorific, caldura (in **condensator**), numit **agent termic;**

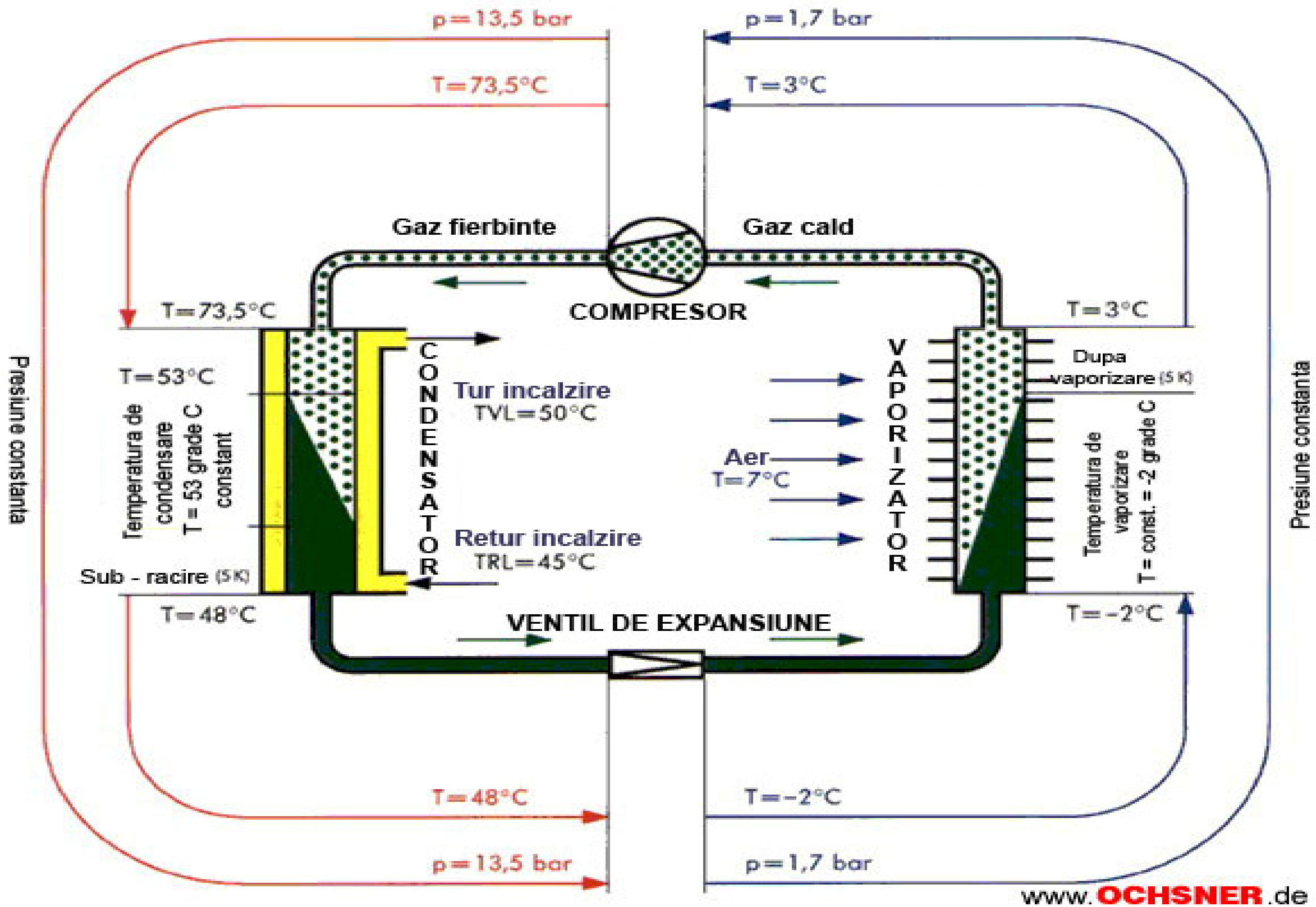
Agentul frigorific, pe linga faptul ca are un punct de fierbere foarte scazut (cca -2 º C) are si proprietatea de a acumula energie transfomindu-se din stare lichida in stare gazoasa si poate usor ceda aceasta caldura revenind la starea lichida initiala**.**

- In momentul cind agentul frigorific devine gaz prin preluarea caldurii sursei reci, acesta este introdus intr-un compresor (doar gazele se pot comprima - lichidele sunt incompresibile) iar in timpul compresiei temperatura agentului frigorific creste cu citeva zeci de grade, suficient sa ajunga la o temperatura mai mare decat a agentului termic si sa-i poata ceda acestuia cadura .

- Dupa ce agentul frigorific cedeaza energia agentului termic, revine treptat la starea initiala (lichida) si este trecut printr-un **ventil de expansiune unde** pierde presiunea acumulata in compresor.

- Din acest moment ciclul se repeta iar pompa de caldura "pompeaza" caldura dinspre sursa rece spre agentul termic - bineinteles prin intermediul agentului frigorific si cu aportul compresorului .

Schema de functionare a unui PDC aer-apa



Frigiderul este de fapt tot o PDC care insa functioneaza invers fata de cele prezentate mai sus: el raceste o incinta si incalzeste aerul din imediata vecinatate. Oricum aceste masini sunt si reversibile!

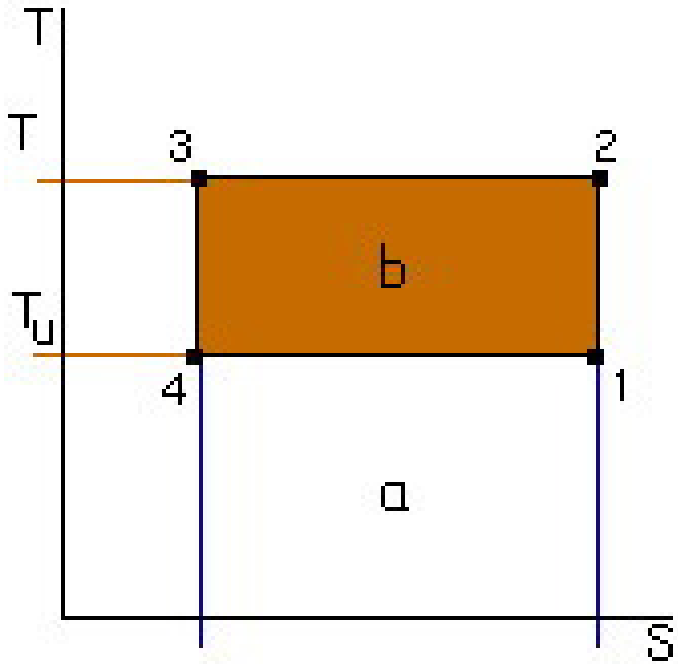
Ciclul Carnot inversat este ciclul dupa care functioneaza o pompa de caldura cu comprimare de vapori actionata electric (prescurtat PDC).

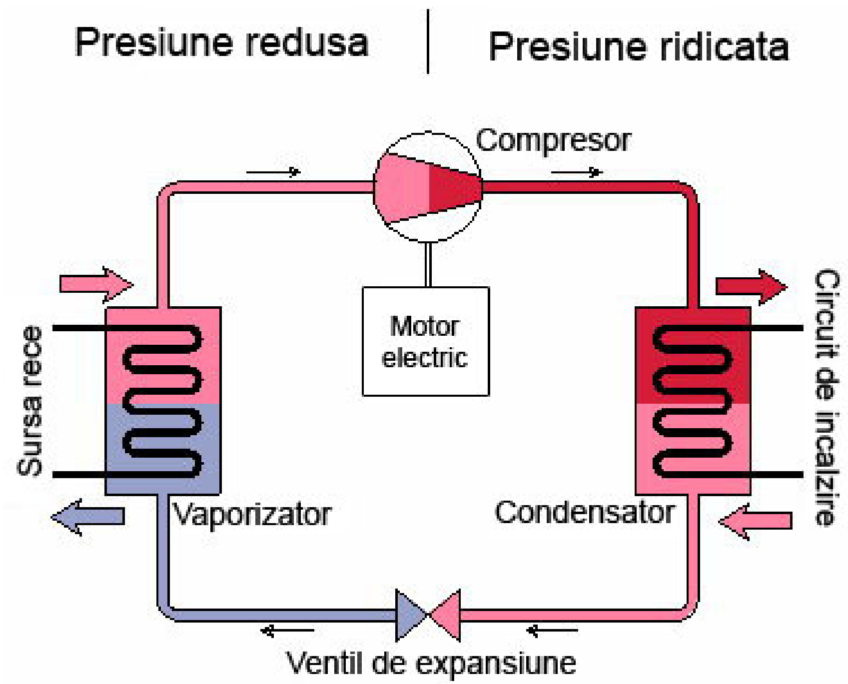
Diagrama T-S a Ciclului Carnot inversat si ideal:

4 -1 > vaporizare

2 - 3 > condensare

3 - 4 > expansiune





unde:

T=temperatura corpului care primeste caldura (agentul termic)

Tu= temperatura corpului din care se extrage caldura (sursa rece)

e=coeficient de eficienta dupa Carnot

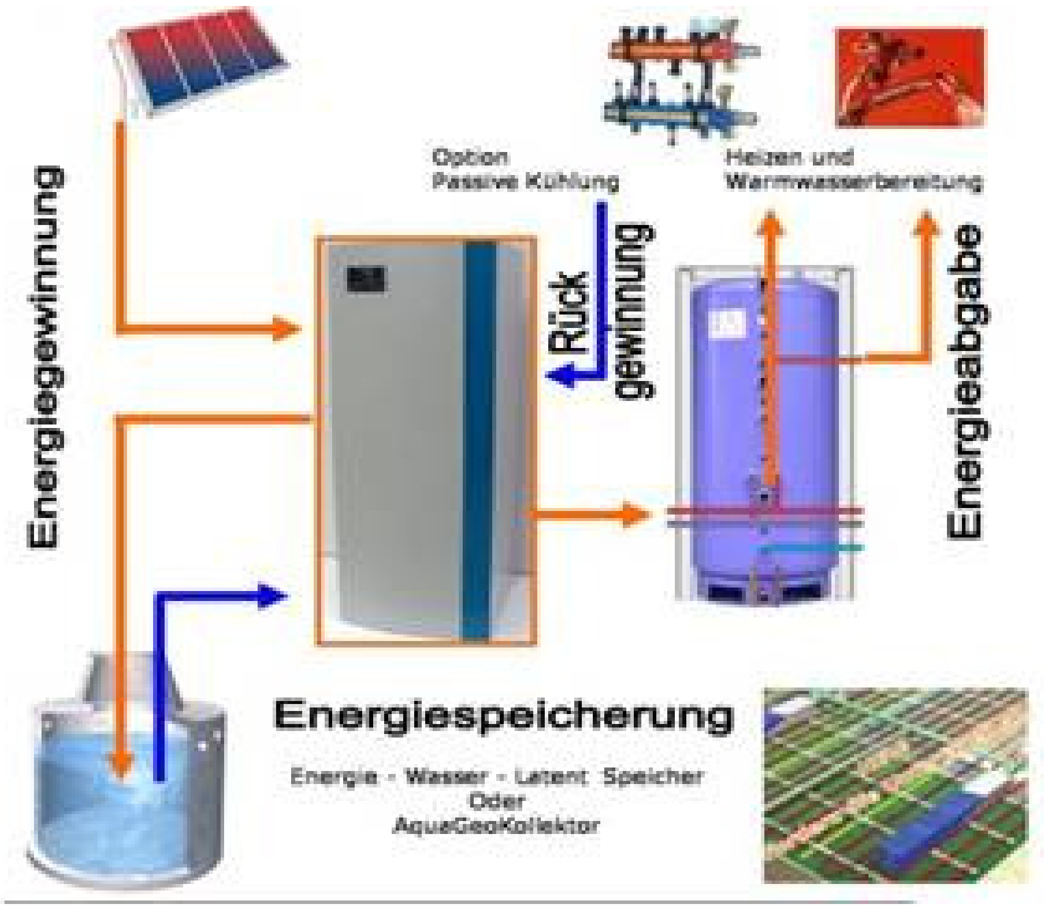
T-Tu = diferenta de temperatura intre corpul cald si corpul rece (temperatura exprimata in grade absolute Kelvin)

e = T/T-Tu

- Suprafata a = energia preluata din mediul inconjurator
- Suprafata b = energia consumata de compreseor
- a+ b = energia totala cedata agentului termic
- s = entropia (continutul de energie la o stare data)

sistem hibrid

- a fost creeat un sistem hibrid cu PDC si panouri solare numit PDC solara.Va prezentam schema de primcipiu:



ADVANTAGES OF HEAT PUMPS

- Heat energy contained in the outdoor environment is a renewable and practically unlimited resource.
- For heat pumps operating in cooling mode, the outdoor environment is a practically infi nite heat sink.
- Heat pumps are the most effi cient known method of using electricity to heat the indoor environment, provided the outdoor temperature is warmer than approximately 4^0C. They actually deliver more heat energy into the house than they demand from the electric utility.
- Because heat pumps work best when they are called upon to provide a constant indoor temperature, it is not necessary to change the thermostat setting unless you plan to be out of the house for several days.
- The exhaust from a heat pump is either cold or warm air, depending on the mode. There is no CO produced, nor any other noxious gas. (Some pollution is generated, however, at the distant electric power plant if it burns fossil fuels.)
- Ground source heat pumps with suffi ciently deep outdoor coil systems can function well even in places where winters are severe. At a depth of several meters beneath the surface, the temperature is constant and is at least 10^0C in most locations.

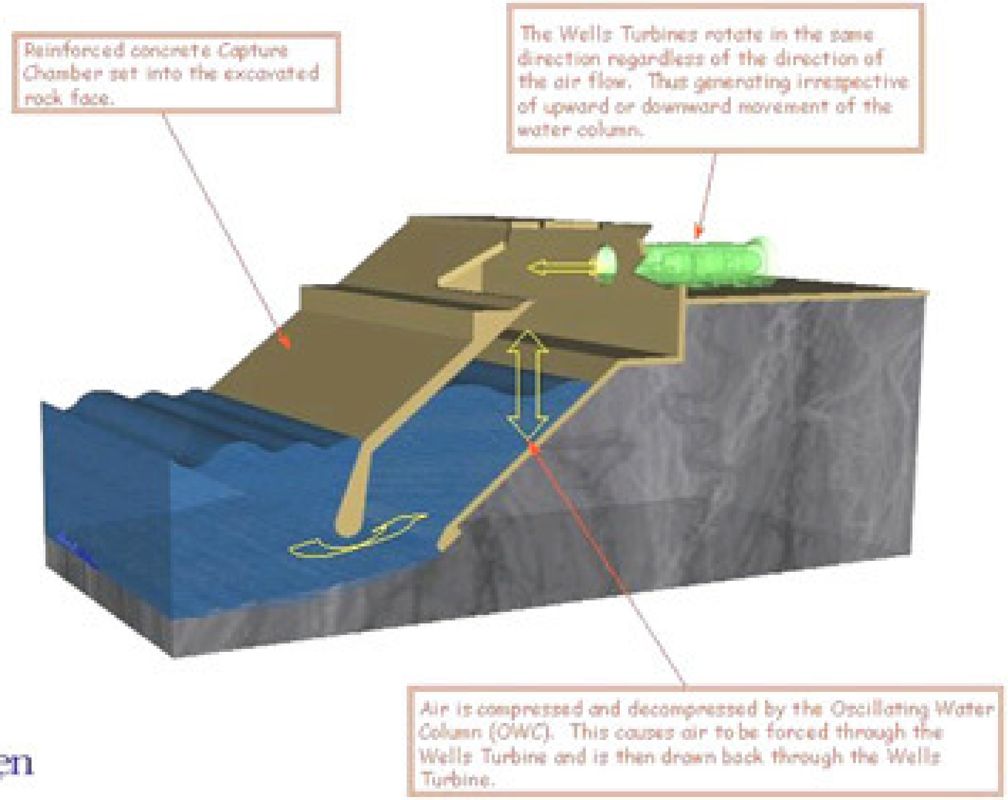
LIMITATIONS OF HEAT PUMPS

- Air exchange heat pumps work well if the outdoor temperature is warmer than about 4^0C, but if it gets colder than that, there is not enough thermal energy in the outdoor air to allow effi cient operation.
- In older systems that use *chlorofluorocarbon* (CFC) refrigerant compounds, the potential for *ozone depletion* is an issue. A small amount of CFC can destroy large numbers of ozone molecules. Ozone helps to shield the earth’s surface from excessive solar UV rays.
- The air that comes from a heat pump is near 35^0C. This is warmer than the typical indoor environment, but it won’t heat up a cold house very fast.
- Heat pumps are relatively expensive to install new. This is especially true of the deep ground source type. It may take a long time for a new system to pay for itself.

Ocean Wave Energy

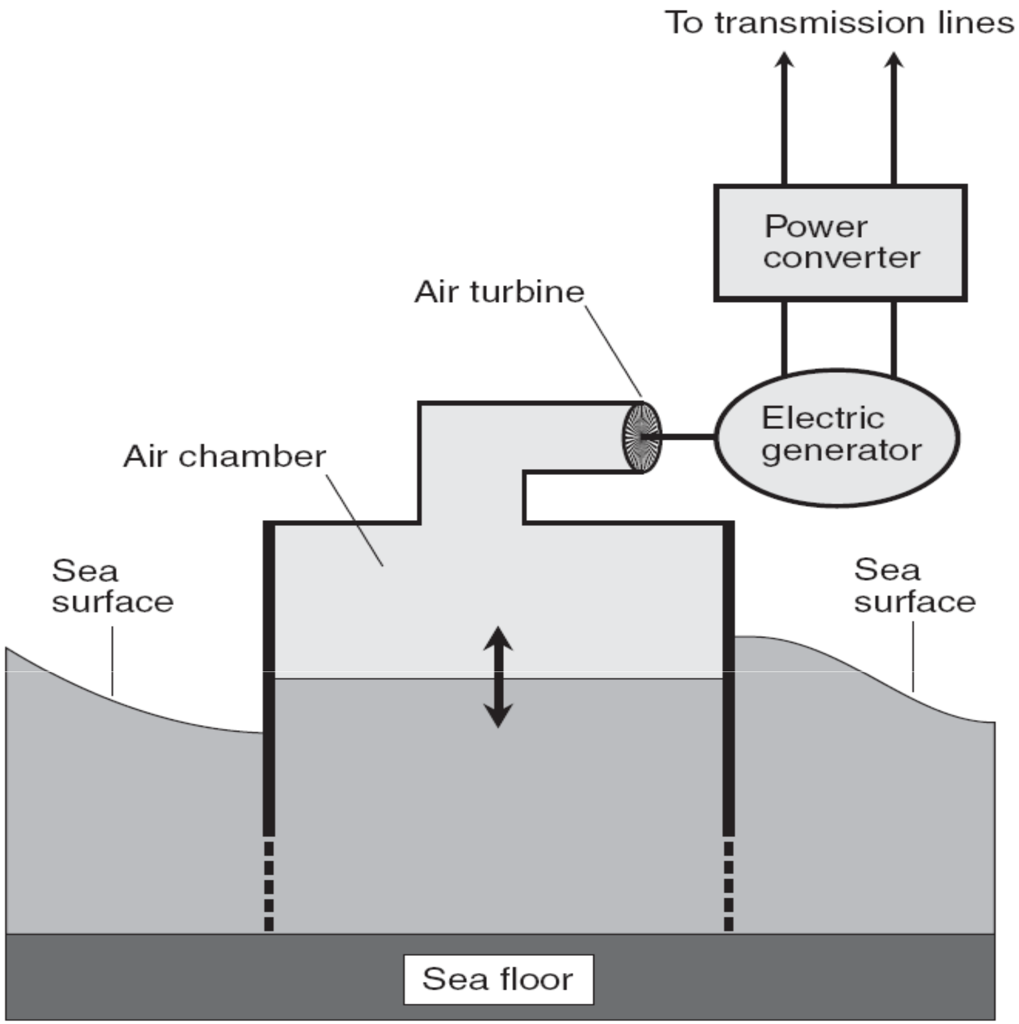
- The idea of harnessing energy from the ocean's waves was tossed around for a couple hundred years. But it wasn't until the oil crisis of the 1970s that it started to gain some significant attention

- **Terminator: Wave energy devices oriented perpendicular to the direction of the wave, are known as terminators. These terminators include a stationary component and a component that moves in response to the wave. The "stationary" part could be fixed to the sea floor or shore. It must remain still, in contrast to the movable part. The moving part works kind of like a piston in car -- moving up and down. This motion pressurizes air or oil to drive a turbine.**



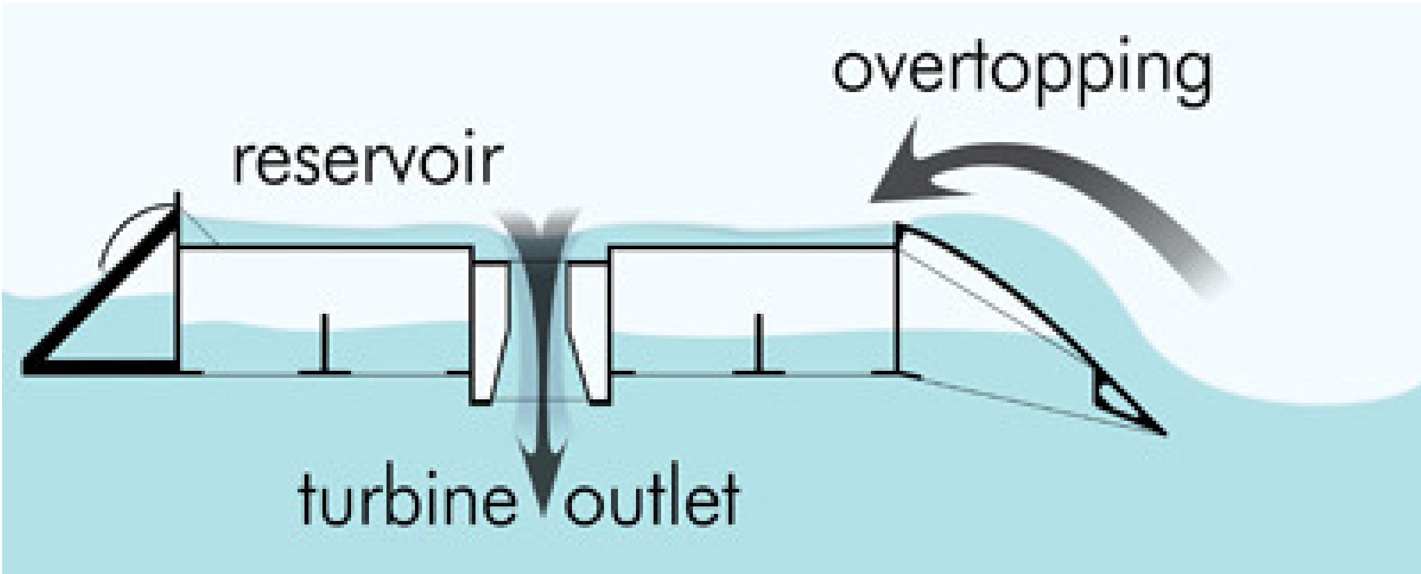
Wavegen

- An **oscillating water column (OWC)**, shown in the image above, is a terminator. OWCs have two openings -- one on the bottom that allows water to enter the column and one narrow passage above to let air in and out. As waves come and fill the column with water, this pressurizes the air inside, which forces the air through the opening above. The air encounters and drives a turbine. Then, as waves pull away, water rushes out, which sucks more air back down through the top, driving the turbine again.

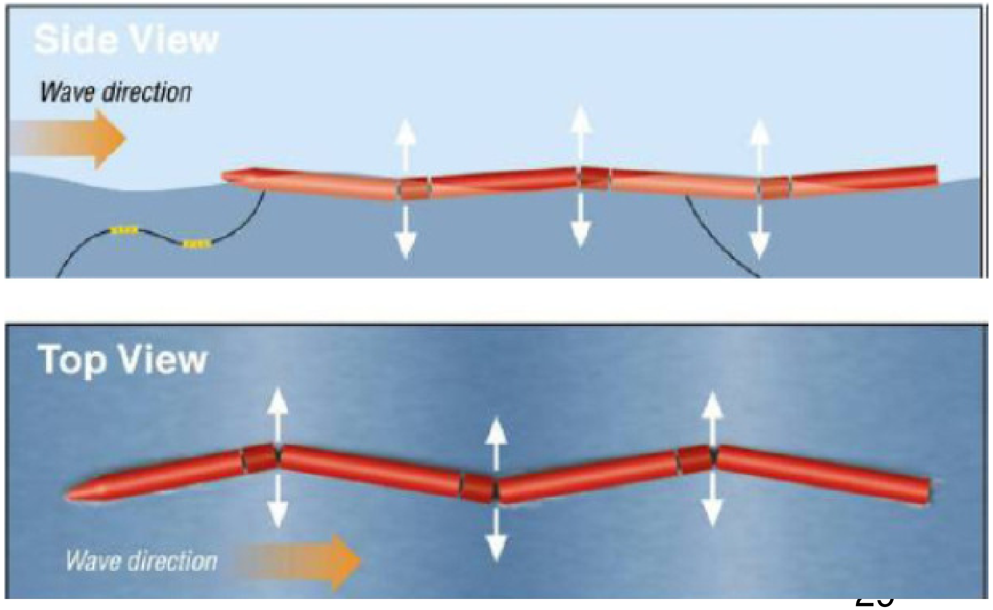


Simplified functional diagram of a wave-electric power-generating system

- Another terminator, an overtopping device, includes a wall that collects the water from rising waves in a reservoir. The water can escape through an opening, but while passing through, drives a turbine. The most famous kind of terminator, however, is truly the Schwarzenegger of WECs. Salter's Duck includes a bobbing, cam-shaped (tear-shaped) head that drives a turbine. Though not fully realized, theoretically, this device would be the most efficient WEC.

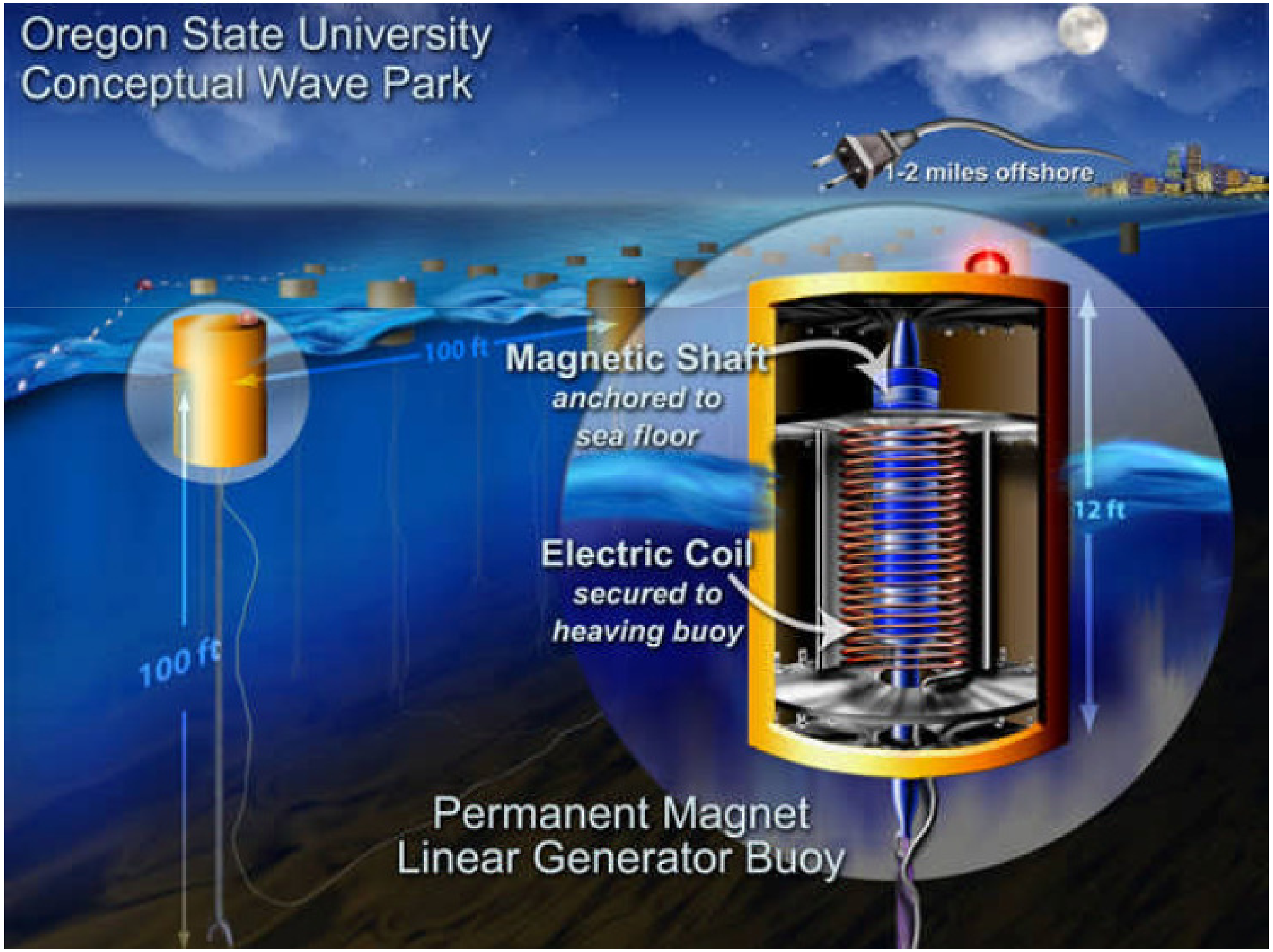


- **Attenuator**: These devices are oriented parallel to the direction of the wave. One of the most well-known examples of this is the **Pelamis**, a series of long cylindrical floating devices connected to each other with hinges and anchored to the seabed. The cylindrical parts drive hydraulic rams in the connecting sections and those in turn drive an electric generator. The devices send the electricity through cables to the sea floor where it then travels through a cable to shore
- http://www.youtube.com/watch?v=F0mzrbfzUpM&eurl=http%3A%2F%2Fhome%2Eclara%2Enet%2Fdarvill%2Faltenerg%2Fwave%2Eht m&feature=player_embedded



- A similar concept is used by the Pelamis (designed by Ocean Power Delivery Ltd. [2006]), which has four 30-m long by 3.5-m diameter floating cylindrical pontoons connected by three hinged joints. Flexing at the hinged joints due to wave action drives hydraulic pumps built into the joints.
- A full-scale, four-segment production prototype rated at 750 kW was sea tested for 1,000 hours in 2004. This successful demonstration was followed by the first order in 2005 of a commercial WEC system from a consortium led by the Portuguese power company Enersis SA.
- The first stage, scheduled to be completed in 2006, consists of three Pelamis machines with a combined rating of 2.25 MW to be sited about 5 km off the coast of northern Portugal.
- An expansion to more than 20-MW capacity is being considered. A Pelamis-powered 22.5-W wave energy facility is also planned for Scotland, with the first phase targeted for 2006

Rendition of a Wave Farm Made Up of Permanent Magnet Linear Generator Buoys



ADVANTAGES OF WAVE-ELECTRIC POWER

- The turbulence of the world's oceans is a renewable resource.
- The conversion of wave power to electricity does not generate CO_2, CO, NO_x, SO_x, particulates, ground contamination, or waste products.
- A wave-electric generator is not particularly expensive to install or maintain, as long as it is engineered to withstand storms (without wasteful over engineering).
- Large "wave-electric power farms" can produce great quantities of usable electricity.
- Wave-electric generators have a low profile. Even when observed, they blend in fairly well with the scenery. (However, this can also be a problem; note the last limitation on the next page.)
- Wave-electric generators, if properly designed, do not have a significant adverse effect on marine life.

LIMITATIONS OF WAVE-ELECTRIC POWER

- When the ocean surface is calm or nearly calm, a wave-electric generator will not produce usable output.
- Wave-electric generators must be sited carefully to minimize the effects of the noise they produce, but they must nevertheless be located where the energy from swells is available in suffi cient amounts.
- A "hundred-year storm" may destroy a wave-electric generator unless it is overengineered to the extent that its cost does not justify its use.
- Wave-electric generators, because of their low profile, may present a hazard to marine navigation unless their presence is made clear on maps. Buoys or other markers may be necessary.

Electricity storage technologies

- Batteries
- Flywheels
- Ultracapacitors
- Superconducting magnetic
- Others

Sustainable Development –International and European Context / Priorities

- Kyoto Protocol (1997), requires industrialised countries to reduce greenhouse gas emissions by 5.2% below 1990 levels by 2008-2012.
- European Commission (2000): Strategic Objectives 2000-2005 –Shaping the New Europe, identified Energy as a key factor for Europe's competitive and economic development.
- Mr. Prodi, former president of European Commission: Europe in a post-fossil-fuel era, when homes would generate the power they need from renewable sources like the wind and the sun, store it in hydrogen fuel cells (Brussels, Oct. 15, 2002).
- Speaking for the EU in Johannesburg (2002): EU had set a goal of obtaining 22 % of its electricity and 12 % of all energy from renewable sources by 2010

Sustainable Energy Systems

- Sustainable Energy Systems - EC Priority, on short and medium term: "maintaining the stability of the electricity grid as the installed capacity of distributed generation using RES is increased", "actions aimed at demonstrating the optimal use and management of distributed generation and storage to address existing and potential bottlenecks", "achieve an increase in the security of distribution grids" .
- The EU's "ENERGY FOR THE FUTURE: RENEWABLE SOURCES OF ENERGY - White Paper for a Community Strategy and Action Plan", includes a campaign to encourage large scale deployment of renewables.
- Energy storage solution - both environmentally friendly and with potential for cost effectiveness, is to produce hydrogen when and where renewable energy sources are available, and to convert it later to electricity.
- Europe's push for hydrogen is also motivated by the desire to meet its commitments to cut greenhouse gases under Kyoto global warming treaty
- Converting Europe to a decentralized energy grid, based on hydrogen fuel cells placed near the point of energy consumption, is identified as the way forward in European energy policy, despite estimation by Mr. Prodi that cost would be "five times the cost of installing a mobile-phone network".

National policies / programmes of some European countries

Italy

- In ***Italy***, it is an official target to increase the contribution of renewable energy sources up to 22% of the total energy demand of 340 TWh, by year 2010. To reach this objective, the Italian Government, in accordance with the EU's Energy White Paper, intends to introduce the carbon tax and also important fiscal facilities for the enterprises interested in this sector (*The Italian Normative Framework in Matter of Support to the Renewables Sources of Energy*, 2002).
- The feed-in tariffs are comparatively low – around 0.15 € per kWh

France

- France’s first feed-in tariff is currently in place after an agreement could be found for the regulation of interconnection and metering with the utility Electricite de France (EDF).
- For systems installed in the first year, the PV tariff, guaranteed for 20 years, will be 0.15 €/kWh in France and twice that for French overseas Departments and Corsica (0.30 €) and will decrease by 5% annually for systems installed in succeeding years.
- The scheme will cover residential systems up to 5 kWp, non-building systems (such as noise barriers) up to 150 kWp, and commercial and public buildings up to 1MWp.

Denmark

- wind power already contributes 25% of Danish Electricity and the official aim is to increase this to 50 % by the year 2030 (The IEE Power Engineer, February 2003).
- the feed-in tariffs are at the same level as the customer tariffs (net metering). In addition to the mostly low feed-in tariffs, the governments of Belgium and Denmark support the investment cost in different magnitudes.

Spain

- With Royal Decree 2818/1998 the sell-back rate for PV electricity is fixed at 0.4 €/kWh for systems with a power of less than 5kWp and 0.2 €/kWh above. The Spanish law has several shortcomings that have so far prevented a strong development of the Spanish market.

Austria

Since 1 January 2003, the feed-in tariff for PV current has been countrywide 0.60 € per kilowatt hour for PV systems up to a power of 20kWp and 0.47 €/kWh for PV systems above. The feed-in tariff was granted temporarily for thirteen years, and there was a limit of the total installed PV power capacity of 15MWp. This limit is very low and was exhausted rapidly.

Portugal

- Since 1988, the so-called E4-Program has existed. According to this program, the feed-in tariff is 0.50 € for plants with a power up to 5 kWp. For plants with higher power, the feed-in tariff is 0.45 € per kWh. The feed-in tariff is guaranteed for twelve years and there is a limit in the total installed PV power capacity of 50MWp.

Japan

- In Japan, the sell-back rate is 24 Yen (0.21 €) per kilowatt hour. This rate is identical to the electricity rate paid by the customer. This arrangement is also called *net metering*. It has been introduced in some U.S. states and some other countries. It is, of course, more effective in regions with high electricity cost like Japan.

Greece

- The Greek Parliament has approved the long-awaited legislation for solar energy production.
  - No production and installation permits required for PV systems =< 150 kWp. Systems >200 kWp though still require a typical environmental permit.
  - Feed-in-tariffs are guaranteed for 20 years, and they range from 0.4 to 0.5 €/kWh (adjusted annually for inflation and/or increases in retail electricity prices)
- In Greece projects concerned with energy Savings in Buildings, energy auditing, Passive solar Builindings, Wind technologies and Solar collector configurations applied for space heating and agricultrural purposes are encouraged and funded by the Hellenic Ministry of Development (RTD Section) and by the Hellenic Ministry of Education.

Renewables in UK

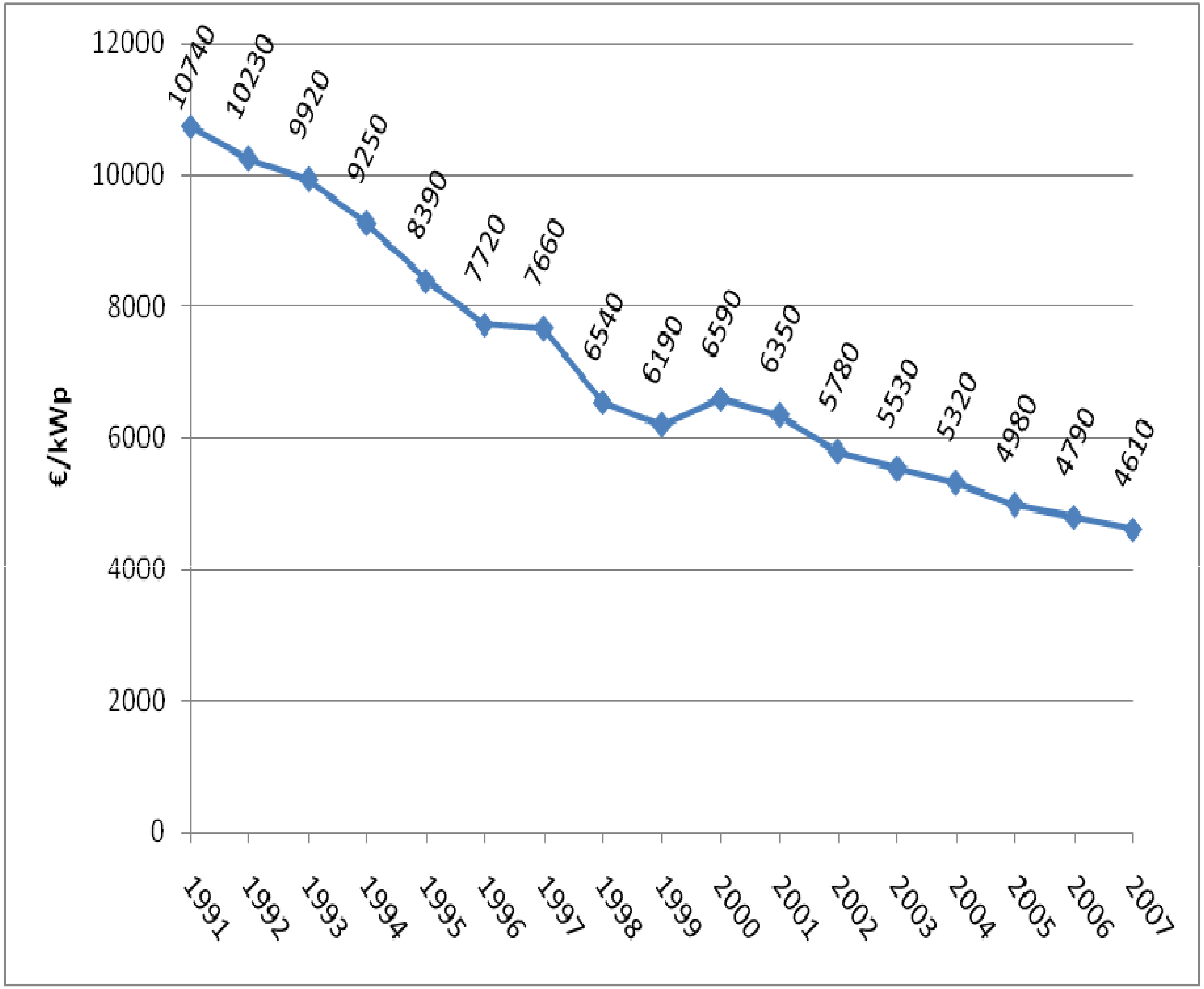
- The government has a target of increasing generation from renewable energy sources to 10% by 2010. It is planning that a 20% of all electricity be generated by renewable energy sources by 2020.
- The proposed new target of 20% renewable energy generation would make Britain one of the most environmentally friendly producers of energy in Europe, but might raise big issues about the sights of aesthetically unpopular wind farms on mainland Britain, as well as offshore.
- In February 2003, the UK government published the Energy White Paper *Our energy – creating a low carbon economy*. It aims to address three key challenges: the threat of climate change, the implications of reduced UK oil, coal and gas production, and the need to replace or update much of the energy infrastructure.

Ireland

- In ***Ireland***, a range of activities have been initiated under a Climate Change Strategy to meet the country's Kyoto target of GHG emissions.
- This has resulted in particular in a rapid increase in the installed capacity of wind generation in the country, both onshore and offshore.
- This growth is projected to continue over the next 10 years.

Germany

- Since the beginning of 1991, German utilities have had to buy PV electricity fed into the grid at 90% of the average electricity rate of the year before. The mandatory PV electricity sell-back rate in recent years was thus about 0.09 €.
- Each year, the rate for a new model system is determined in order to promote competition and price decrease. The owner of the PV system is guaranteed the rate for the year of installation usually for ten to twenty years.
- Because the German 100,000 Roofs Solar Program ended at 31 December 2003, the German government changed the conditions of the feed-in tariffs for renewable energies fed into the grid. The actual conditions for PV follow.
  - For **PV systems set up in the open countryside**, the feed-in tariff is 0.457 €/kWh.
  - For **PV systems installed on buildings or on noise barriers** up to a power of 30 kWp, the feed-in tariff is 0.574 €/kWh; for PV systems with a power between 30 and 100 kWp, the feed-in tariff for the part of the PV system above 30kWp is 0.546 €/kWh and for PV systems with a power of more than 100 kWp, the feed-in tariff is 0.54 €/kWh.
  - **Facade-integrated PV systems** get an additional bonus of 0.05 €/kWh.



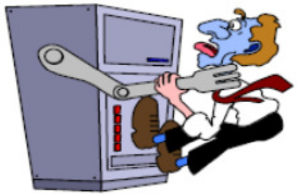
PV system prices

- The system prices for reference PV systems in the range of 2-3 kWp decreased continuously until 1999, and increased slightly in 2000 due both to high demand and a decrease in PV module prices from €10.74 to €6.59 per Wp during the last decade. The total system prices decreased by 39% over the last decade

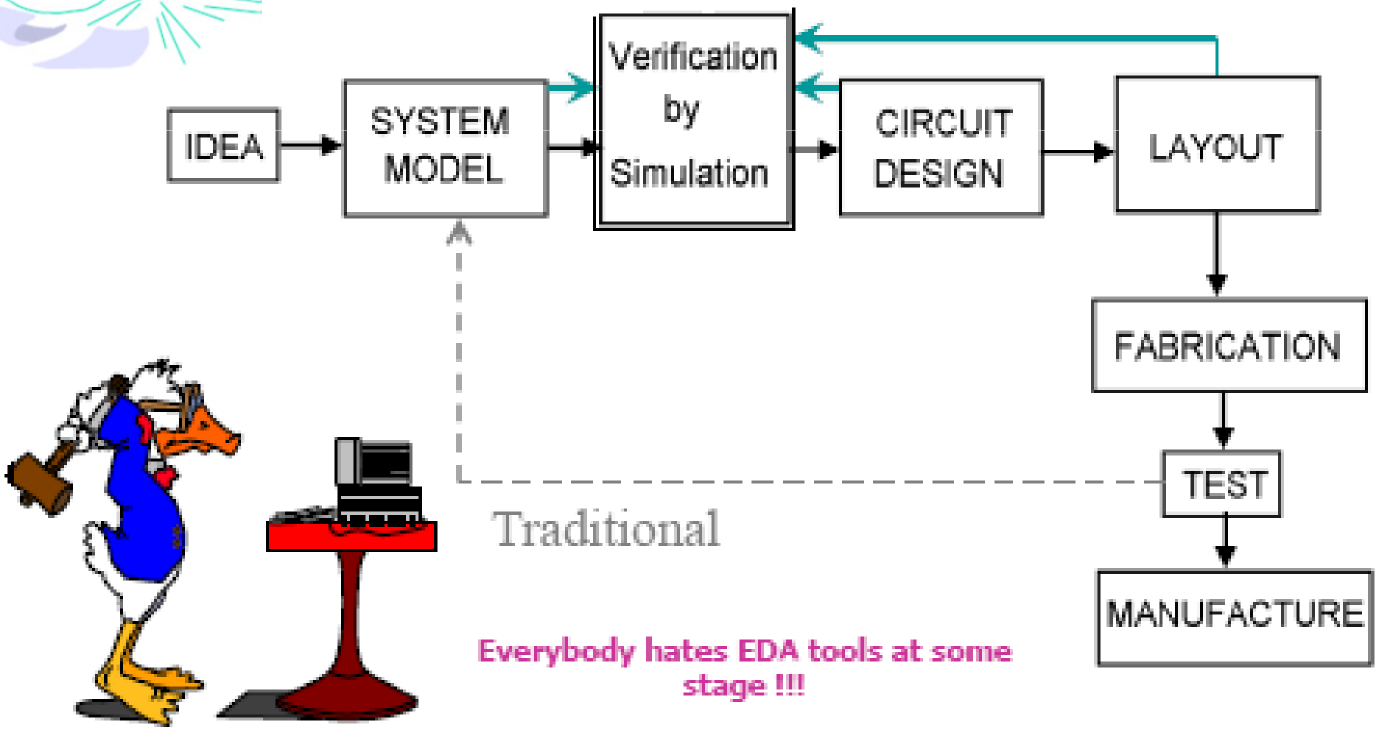
Holistic Modelling and Design

- Traditionally, mathematical models were used to functionally evaluate engineering systems.
- The development of each system component used then to be separately addressed, often involving different software platforms.
- Traditional methods are not able to cope with increased complexity and demands of higher levels of systems integration / faster time to market.
- Recent advances in CAD methodologies/languages has brought the system's functional description and hardware implementation closer.
- Modern Electronic Design Automation (EDA) tools are used to model, simulate and verify a complex engineering system fast, with high confidence in "right first time" correct operation, without producing a prototype.
- High performance electronic controllers can also be implemented.
- The presentation reveals recent work that was carried out in the area of holistic modelling of engineering systems using HDLs.

Design Methodologies – EDA Tools



NOTHING EASIER !



Everybody hates EDA tools at some stage !!!

Modelling and design method

- Traditional development:
  - Each part of system modelling **separately** addressed
  - Use of **different** CAD tools and/or software platforms
  - Design and implementation in **different** environments
- Recent advances in CAD methodologies:
  - Brought the functional description of design and practical hardware implementation **closer**
- They can be **simultaneously** addressed using:
  - Hardware Description Languages (VHDL, Verilog)
  - System level modelling (Handel-C, System-C)

Novel Systems Modelling Method

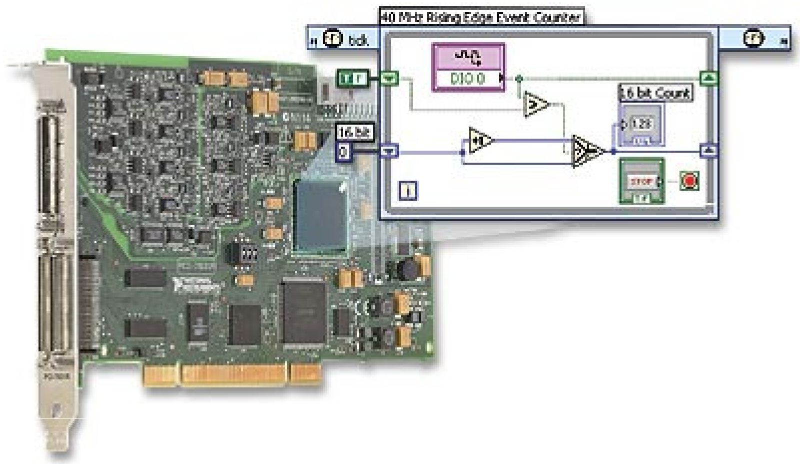
- Extends the traditional use of Hardware Description Languages (HDLs) for electronic circuits design, to encompass holistic modelling of more complex engineering systems.
- Outcome: design environment that allows all aspects of the system to be simultaneously considered, therefore maximising performance.
- Proposed approach correlated with powerful international movement/leading edge research, directed towards system level modelling/design.
- Proposed for engineering systems' holistic modelling:
  - VHDL = Very high speed integrated circuit Hardware Description Language. (IEEE, 1993).
  - Handel-C = new high level language with hardware oriented features
  - New program creaded in LabVIEW

Specific Advantages Offered

- Allows the functional/behavioural description of an engineering system to be combined with a detailed electronic design, on the same CAD platform.
- The mathematical aspects of systems and the electronic hardware design are simultaneously addressed, in a unique environment.
- It is supported by many Computer Aided Design platforms
- Ability to handle all levels of abstraction. The system can be simulated as an overall model during all stages of electronic controller design, which can be subsequently targeted for "system on a chip" implementation.
- Fast implementation & relatively short time to market of new designs.
- Hardware Implementation of Artificial Intelligence is facilitated.
- Versatile reusable models / design modules are generated, in accordance with modern principles of design reuse.

- Development: complex, compact, high performance controllers
- EDA tools enable user to:
  - ➢ Create, simulate, verify a design without hardware commitment
  - ➢ Quick evaluation of complex systems and ideas with very high confidence in the “right first time” correct operation
- The proposed novel approach allows:
  - ❖ All functional aspects of the system considered **simultaneously**
  - ❖ **Maximise** operational performance for high efficiency and power quality
  - ❖ **Rapid prototyping** of a digital controller on an FPGA hardware development platform

The LabVIEW FPGA System



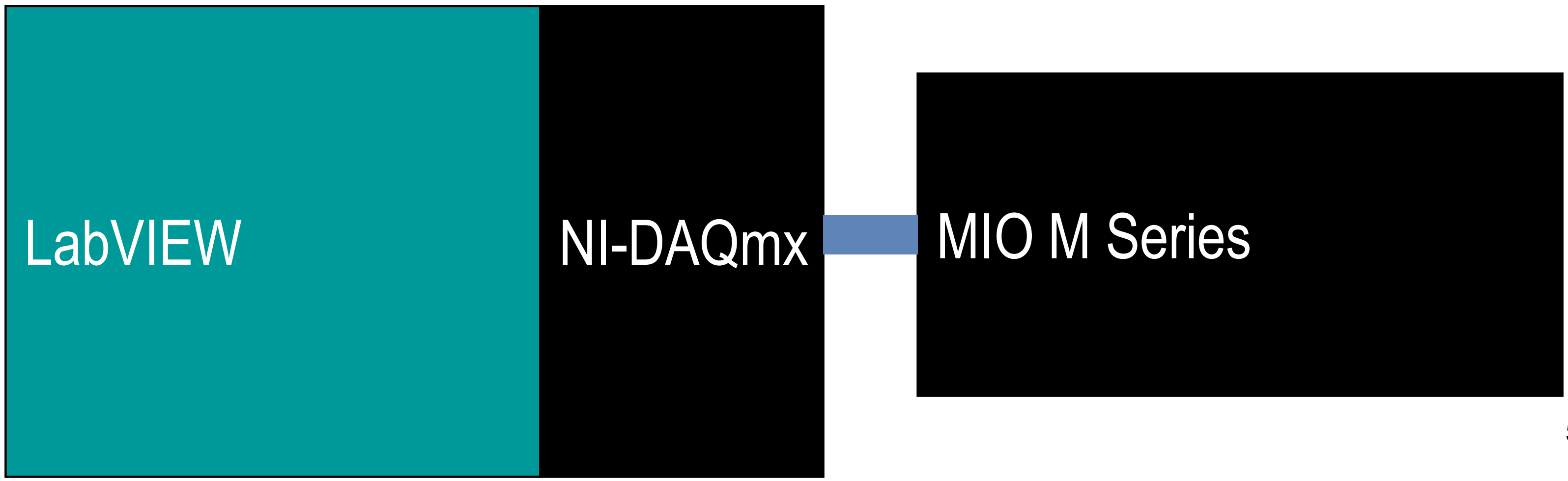
- LabVIEW FPGA Module
  - Software for developing VIs for FPGA target
  - VIs for host PC interaction with FPGA target

- LabVIEW FPGA Enabled Hardware
  - Plug-In Reconfigurable I/O (RIO) boards
  - CompactRIO Modular Reconfigurable I/O System
  - Compact Vision System
  - PXI Timing and Synchronization

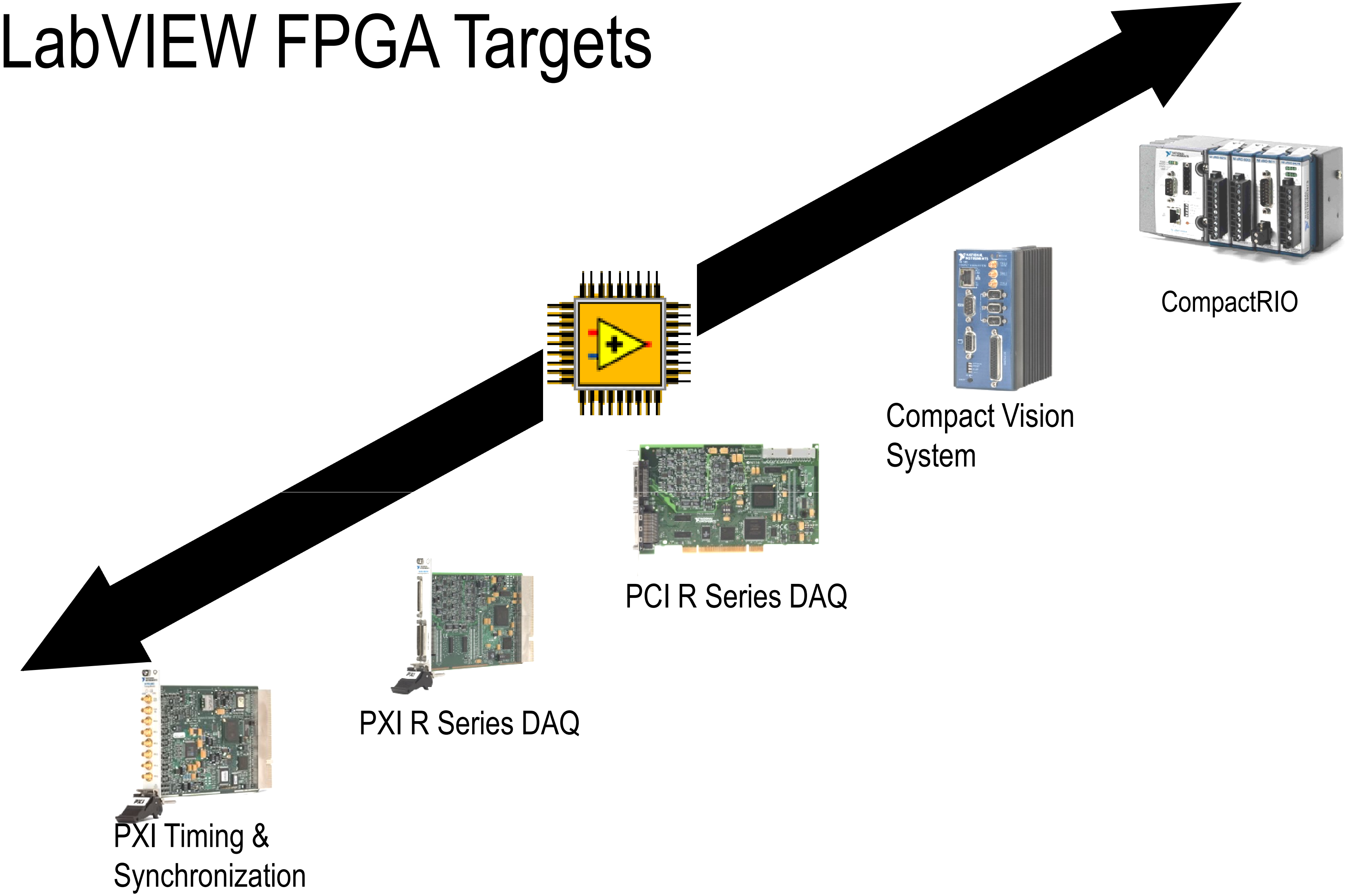
Components of a Measurement System

A traditional system consists of three components

- Application software on the computer (LabVIEW)
- Driver software to interface to the hardware (DAQmx)
- The I/O hardware (M Series MIO)

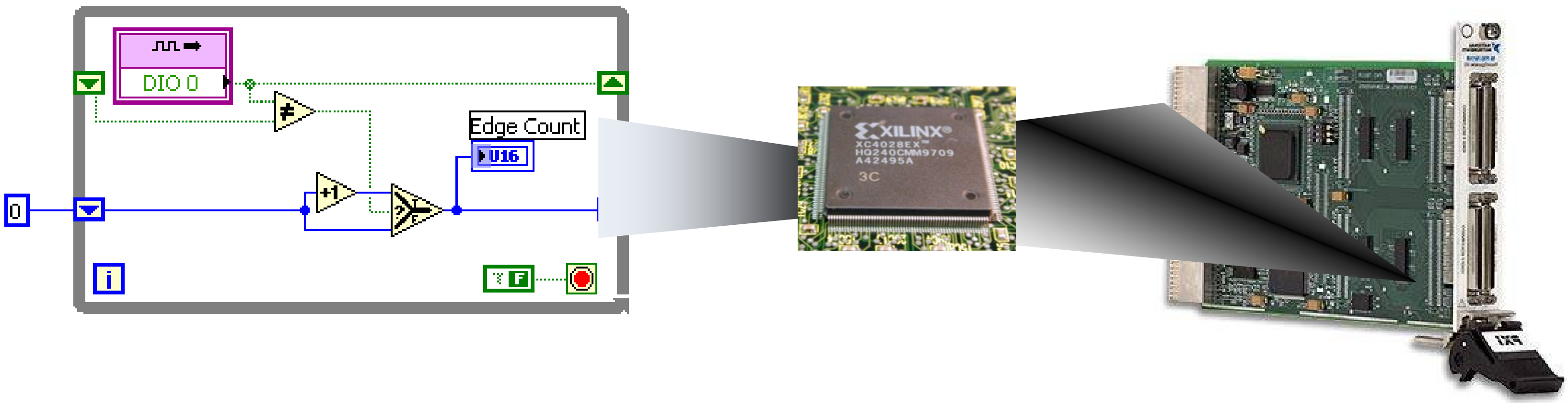


LabVIEW FPGA Targets



The LabVIEW FPGA Module

- Creates VIs that run on the embedded FPGA on NI RIO targets
- Uses LabVIEW graphical programming paradigms
- VIs are compiled before downloading to the FPGA devices

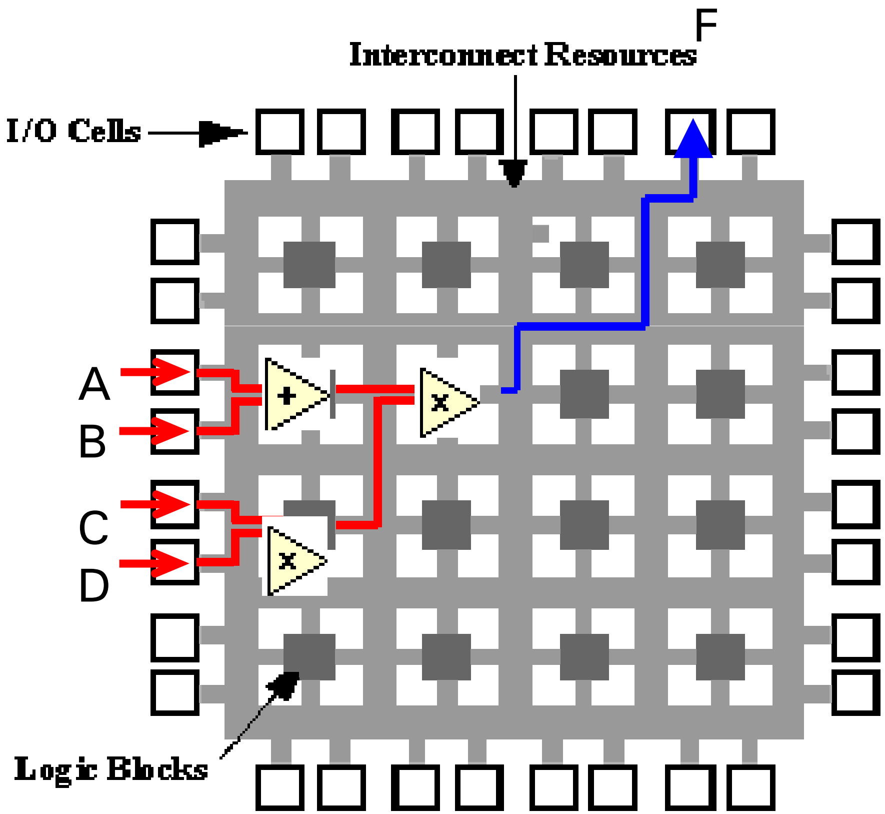


FPGA Industrial Applications

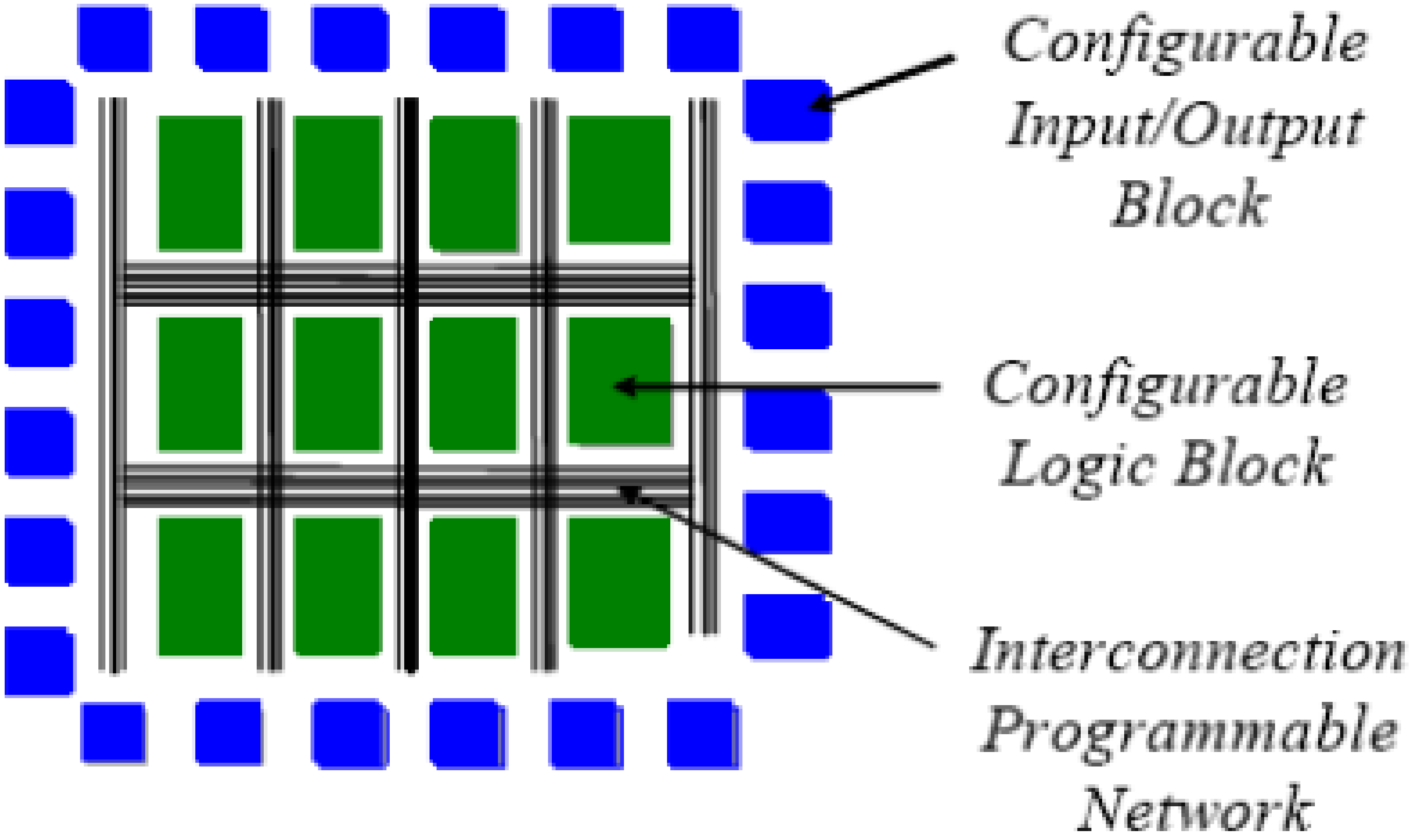
- Telecom, Video, Signal Processing,
- Embedded Systems (Aircraft, Automotive),
- Medical Systems,
- Electrical Systems:
  - PWM inverters,
  - Power factor correction AC/DC converters,
  - Multilevel converters, Matrix converters,
  - Active filters,
  - Fault-detection on power grid,
  - Electrical machines control, speed measurement
  - Neural Network control of induction motors,
  - Fuzzy Logic control of power generators

LabVIEW Mapped to FPGA

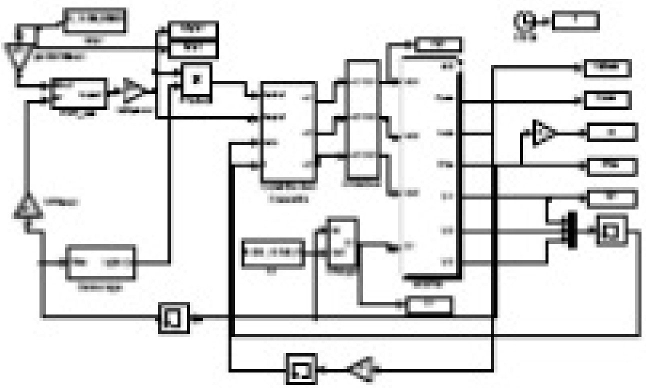
Implementing Logic on FPGA: $F = (A + B)CD$



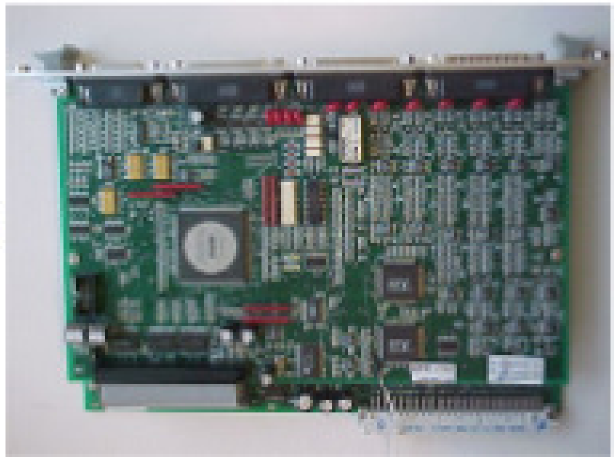
Generic FPGA Architecture



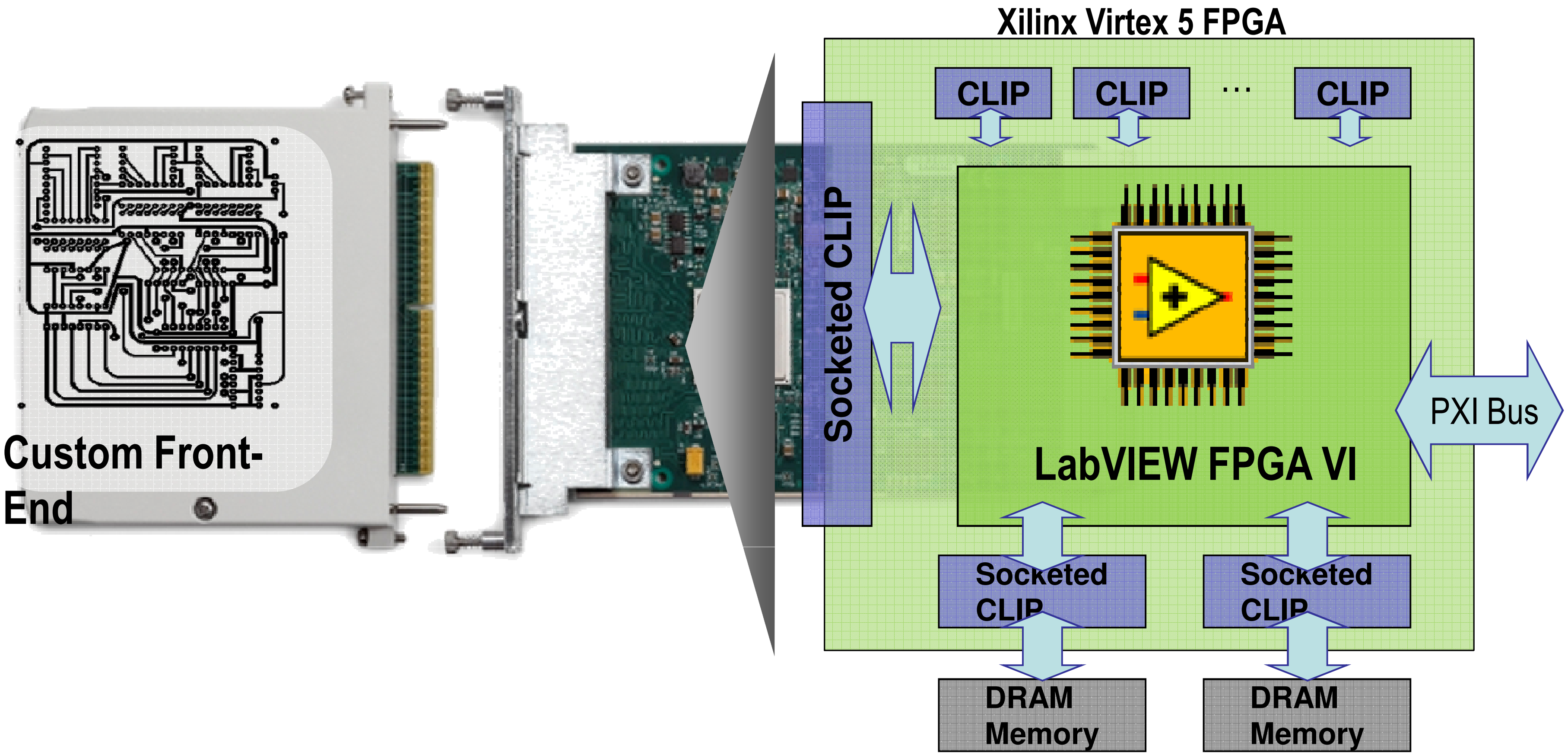
Easily implement a control algorithm on an FPGA-based optimized hardware architecture



Matlab / Simulink Model



FPGA board



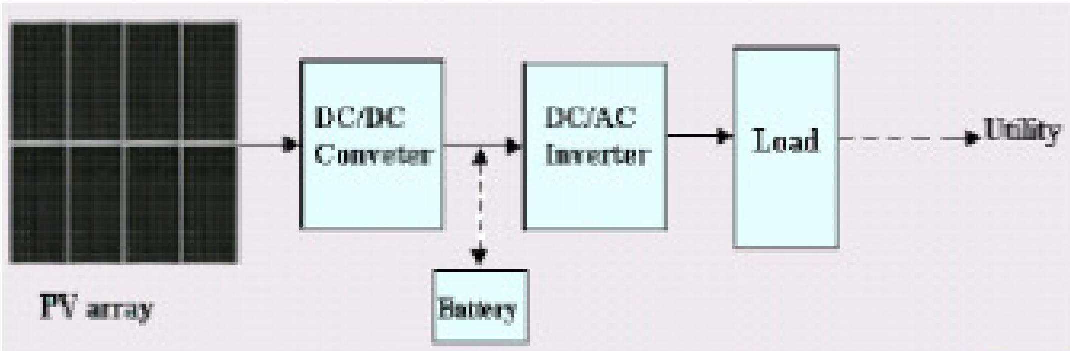
Adaptor Module Requirements:

- Requires PCB layout experience
- Custom HW design for I/O
- Mapping to FPGA I/O pins

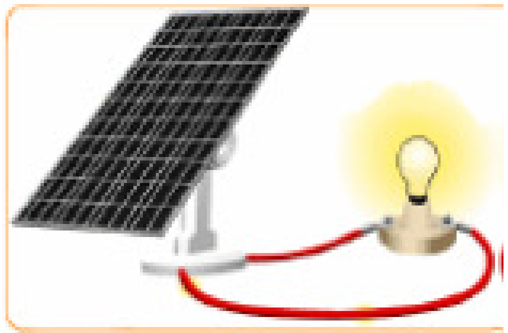
Programming Requirements:

- VHDL Experience
- LabVIEW FPGA
- LabVIEW Host Interface

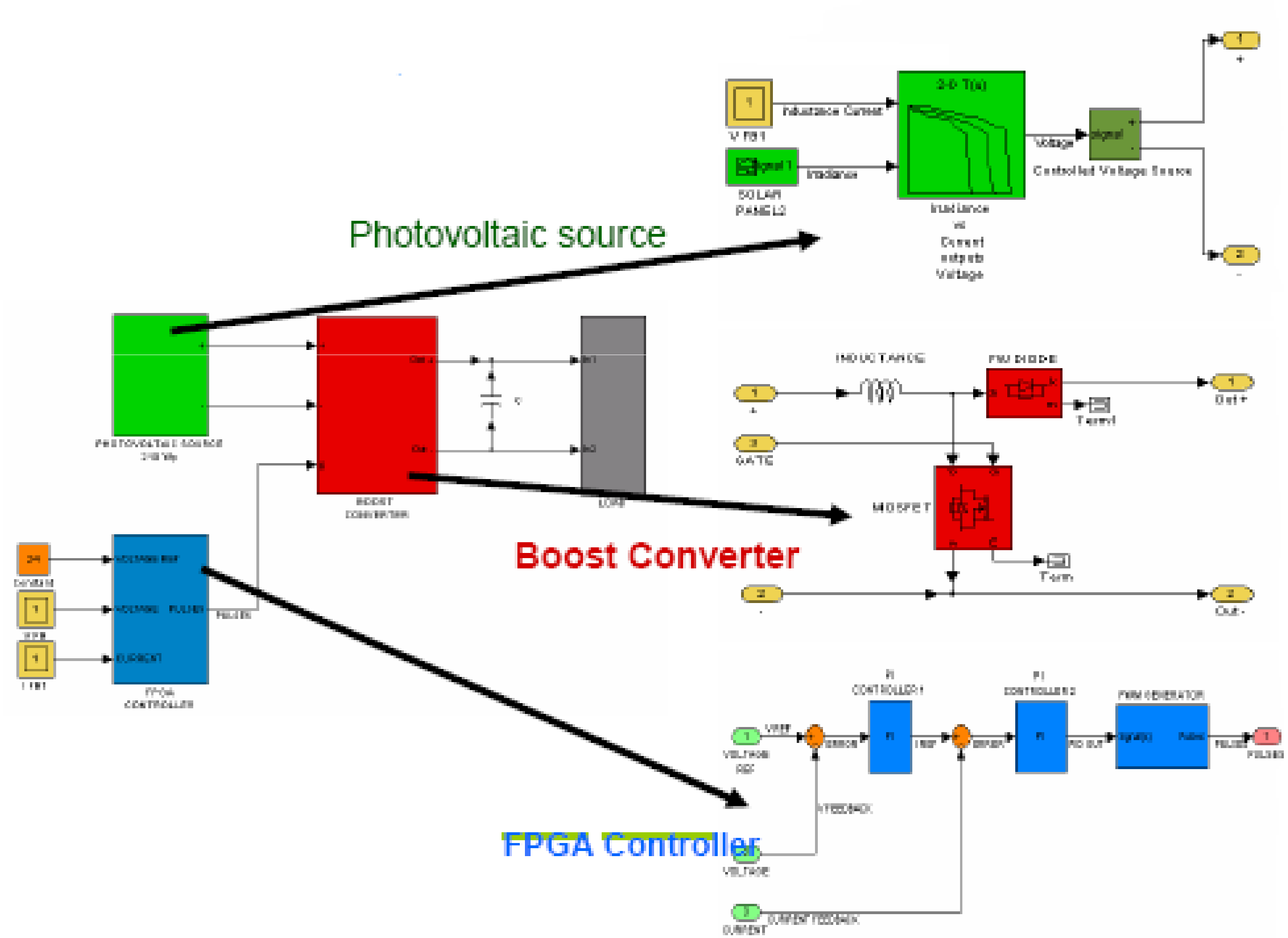
Photovoltaic power system topology



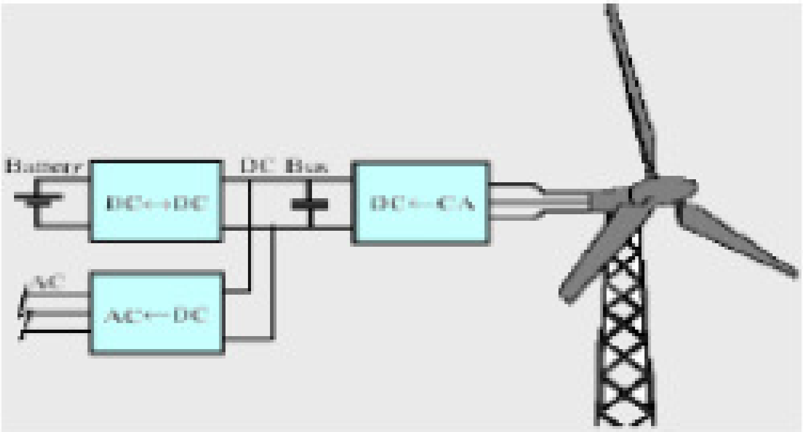
- **Basic design**
  - Photovoltaic array
  - DC-DC Converter (i.e. Boost)
  - Inverter
  - Storage system



Matlab
PV Control System

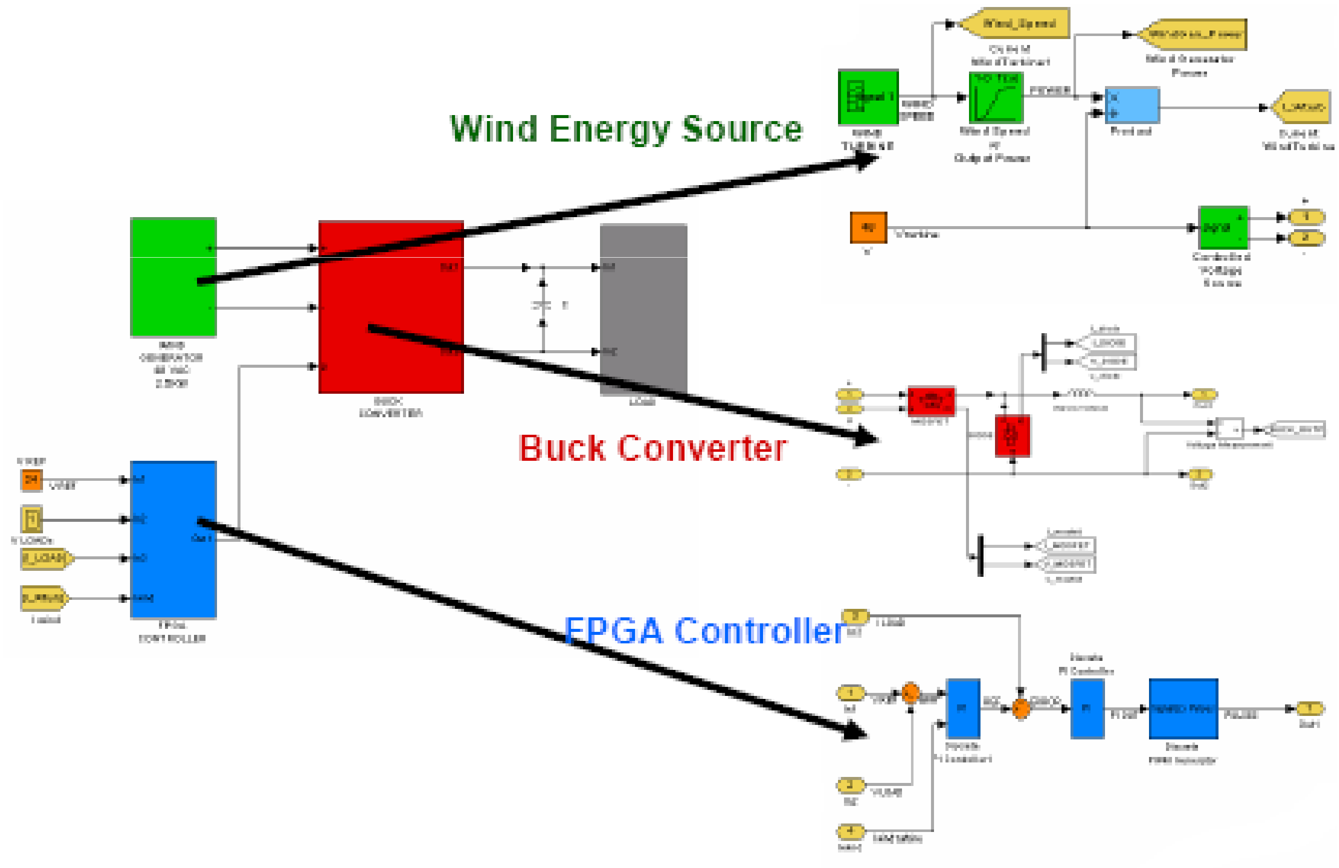


Wind power system topology



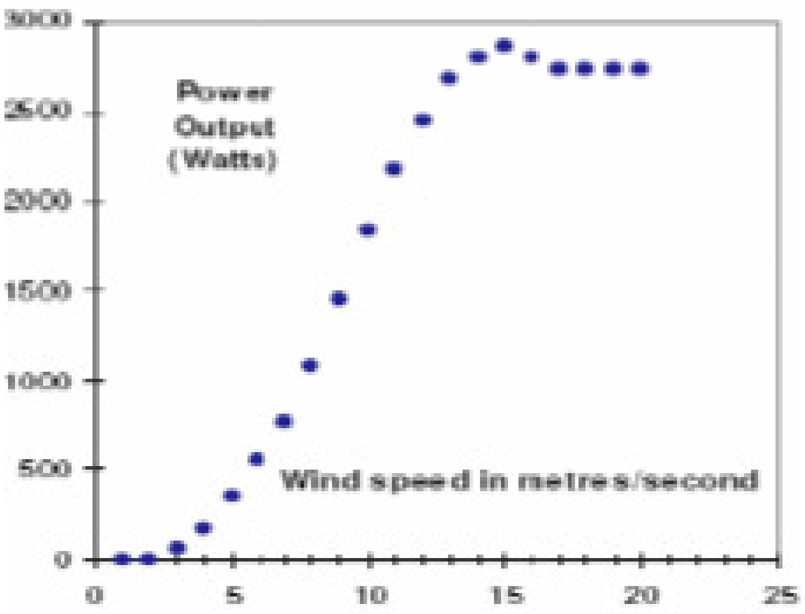
- **Basic system**
  - Wind Turbine
  - Rectifier
  - Inverter
  - DC-DC Converter
  - Batteries

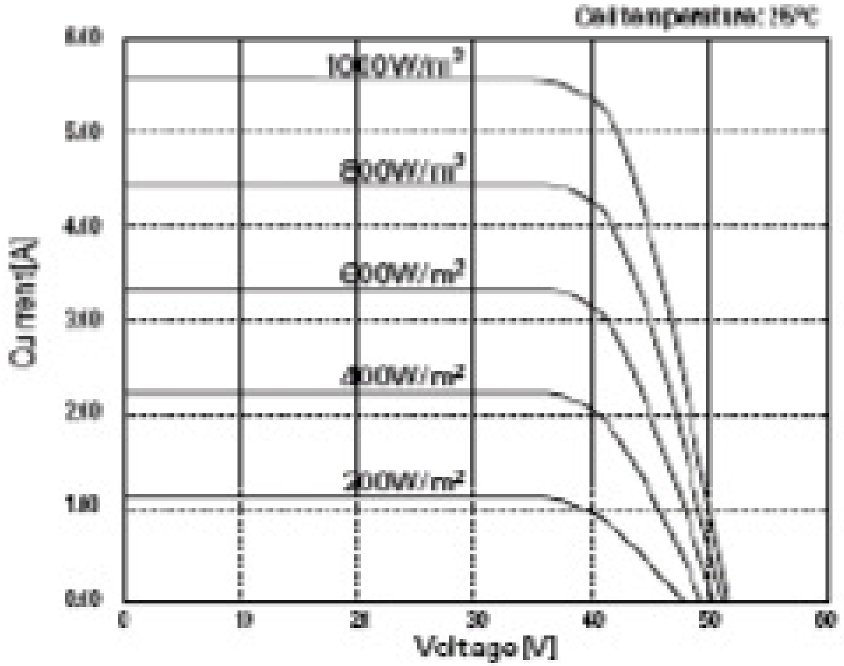
Matlab
Wind Control system



Integrated Renewable Energy Systems

Wind and Photovoltaic Power Sources

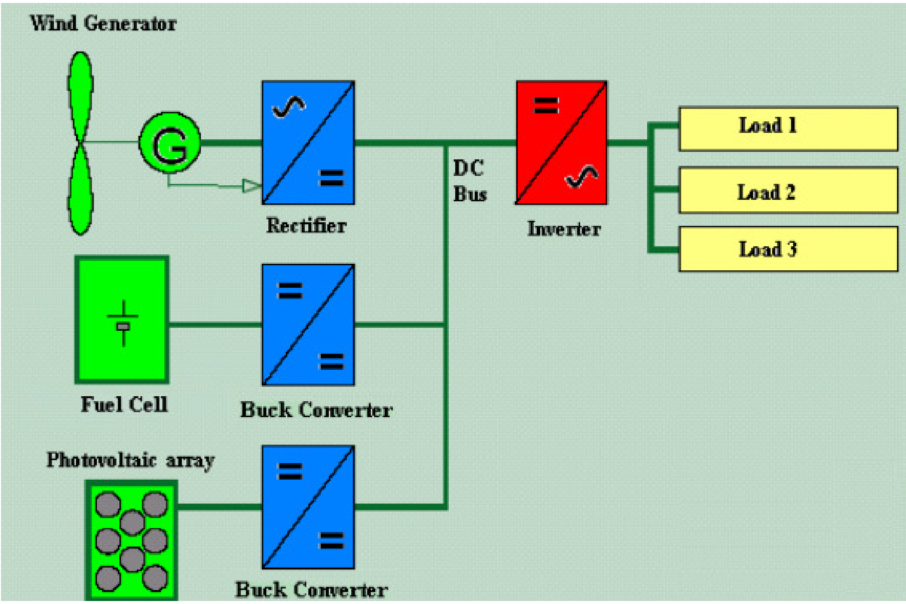




Wind Speed / Power curves

Voltage/Current dependence on irradiance

Integrated DER topology



- Wind generator
- PV generator
- Buck converter
- Boost Converter
- Load
- FPGA Cont

Conclusions on Renewable Systems

- **Novel modelling technique** is proposed for the holistic investigation of power electronic systems.
- Based on **System Level Modelling Languages** (Handel-C) allows **rapid FPGA prototyping** of the controllers.
- The paper presents the particular case of modelling Wind / Solar **power systems** using **Handel-C**, and real-time verification using RC203 FPGA development board.
- System simulated using Matlab/Simulink/SimPowerSystem toolbox to create a **reference for comparison**
- The implemented model shows practically **same results** as the one simulated in Matlab.
- It enables real-time measurement of relevant variables and connection of the implemented controller **directly** to the real power systems.

Conclusions on FPGAs controllers

- The integration of Micro-renewable power resources requires efficient control to achieve optimised use of energy.
- FPGA based controllers have **higher computational** performance and **lower power consumption** than microprocessors, due to parallelism.
- Compared to ASICs, FPGAs have **Lower cost** for initial deployment and **Rapid** deployment and configurability.
- C-based languages are easy-to-understand and widely used, so they are appropriate for controllers design.
- DK5 (Agilent) provides a fast route to physical implementation with early rapid prototyping in programmable logic (FPGAs).