An overview of sustainable energy

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Outline

- Definitions
- Motivation
- Renewable Energies
  - **Solar**
  - **Wind**
  - **Hydrogen**
  - **Biomass**
  - **Geothermal**
- Status of RE [World Wide]
- Status of RE [GCC]
- Future Plans of KSA in RE
- Masters Program at SET

Definitions

Energy: The capacity to do work. KWh

Power: The rate of doing work. [KW = 1000 J/sec]

Energy = Power x Time

Sustainable Energy: Meets the needs of the present without compromising the ability of future generations to meet their needs.

Renewable Energy: Energy systems that are replenished by natural process and not depleted with use as do fossil fuels.

Energy Security: Uninterrupted availability of energy at affordable price.

Motivation

- Energy is the single most important challenge that humanity is facing today.
- The negative impact of fossil fuel on the environment and their depletion has accelerated the search for new energy sources.
- Estimates are that at current consumption rates coal is left for 200 years, Gas for 60 years and oil for 40 years.
- RE have many advantages over the fossil fuels, therefore they are being considered for power generation.

SE4ALL

1.3 billion people (one in five) globally lack electricity to light their home. Twice that number (40%) of the world population rely on wood & coal to cook their food- breathing in toxic smoke that causes lung disease and kills about 2 million people per year.

On 21st December 2012, The UN Gen. Assembly declared 2014-2024 as the decade of Sustainable Energy for All - SE4ALL with the following objectives up to 2030:

- Sustainable energy access for all
- Doubling the rate of Improvement of energy efficiency
- Doubling the share of RE in the global energy mix.

Solar Energy

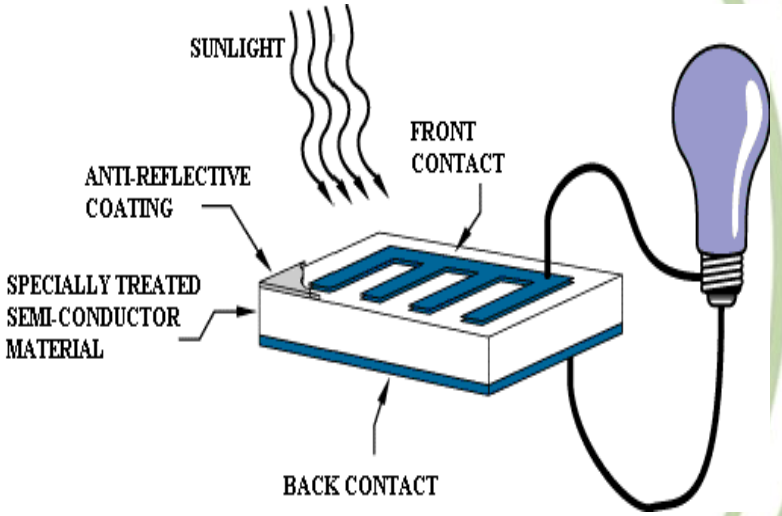
- The fusion of H_2 & He heats the core of sun up to 14 million ^{0}C. Its surface is at about 2 million ^{0}C.
- Sun radiates enormous quantities of energy (10^{31} KW) onto the earth each day since billions of years. Only 1.5 trillionth of this energy reaches earth.
- Earth receives 6000 times more energy every day from the sun than the 6.8 billion people consume.
- 30% of that energy in the form of short wave length radiation is reflected back to space while the rest is absorbed as heat.
- Half of the absorbed energy plays a role in hydrological cycle (evaporation of water). Every year 500,000 km^3 of water needs to be circulated.
- The other half of absorbed energy is used to maintain Avg. temp. at 15^{0}C.

Global Warming

Increase in the CO_2 concentration in the atmosphere is the main source of global warming. The rays of sun which are reflected back from earth are trapped by CO_2 in the atmosphere and they cannot return to space. This leads to global warming. During last few decades, this has led to 0.5 ^{0}C increase in the average temp of the earth.

Photovoltaic (PV) Solar Cell

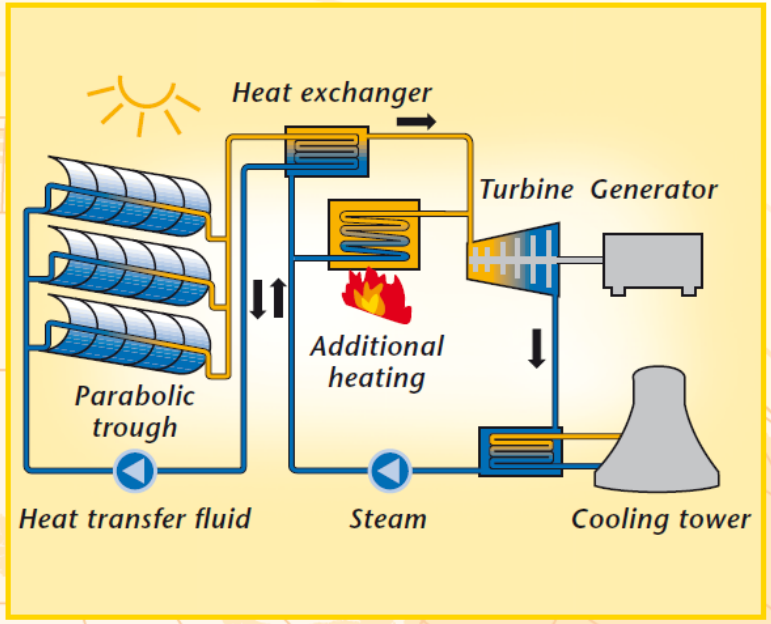
- A photovoltaic solar panel converts solar radiation into direct current electricity.
- There is a photoelectric effect that causes the metals to absorb light photons and release electrons that are captured and create electric current.



Concentrated Solar Power (CSP)

Mirrors are used to concentrate sunlight onto receivers that convert the solar energy to heat. Steam is produced from that heat and goes through a turbine to generate electricity.

The diagram shows how energy transfers from a parabolic trough to usable energy.



Wind Energy

- Wind energy has been used for thousands of years for milling grain, pumping water, etc.
- Wind energy offers the potential to generate substantial amounts of electricity without the pollution.
- When solar radiation enters the earth's atmosphere, it warms different regions to different extent- most at the equator and least at the poles. Since air tends to flow from cooler to warmer regions, this causes air flow that is harnessed in wind turbines to produce power.

Hydrogen Energy

Hydrogen has some unique properties, which in conjunction with electricity make it an ideal energy carrier or fuel. Just as electricity, hydrogen can be produced from any energy source, including the renewable energy sources. Hydrogen can be produced from electricity and can be converted into electricity at relatively high efficiencies. Some processes for hydrogen production directly from solar energy are also being developed.

Hydrogen Energy (Cont.)

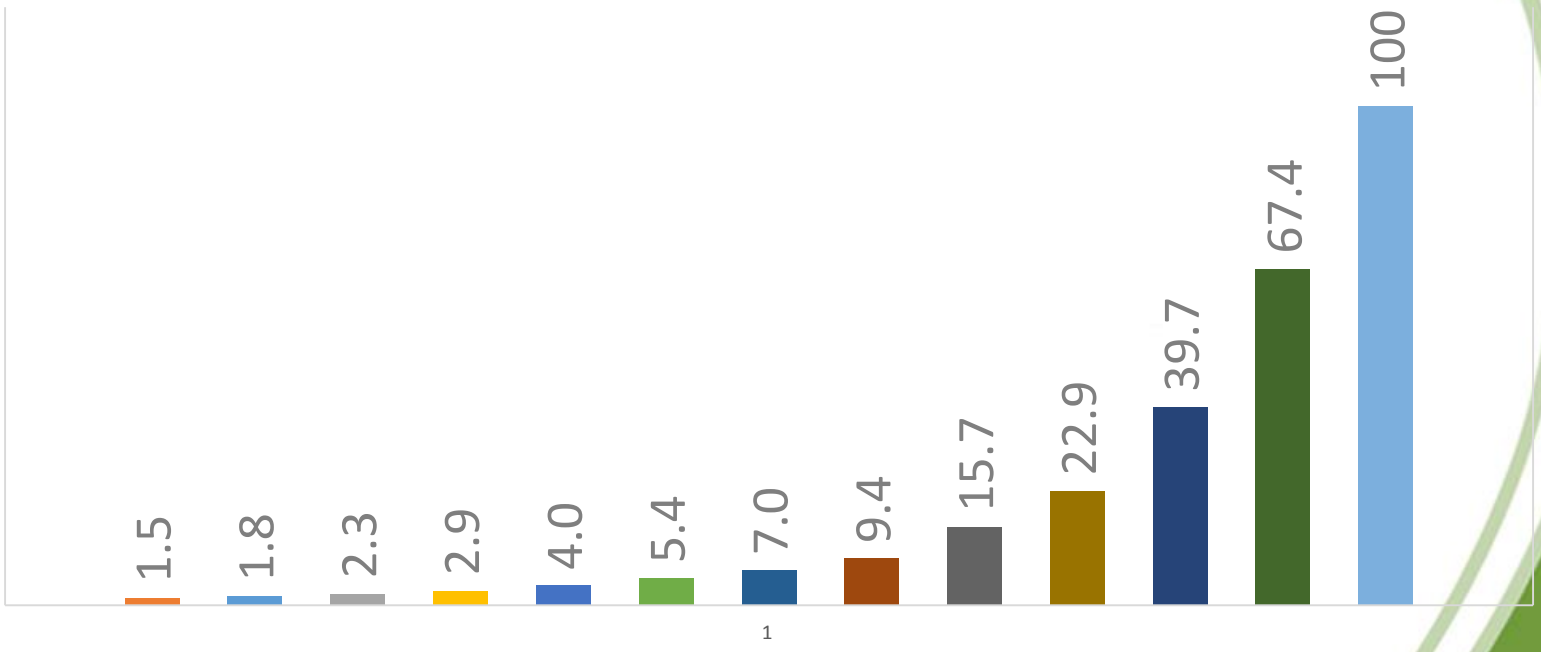
Hydrogen as an energy currency is environmentally compatible, since its production from electricity (or directly from solar energy), its storage and transportation, and its end use do not produce any pollutants or any other harmful effects on the environment.

Biomass Energy

- Biomass is another solar derived RE source. Plants absorb sunlight through photosynthesis which uses CO_2 and water to form sugar. (Biomass from plants and Agricultural waste.)
- Biomass is a very versatile resource that can be used to produce heat, electricity, transport fuels and a range of chemicals and materials.
- Bioenergy is expected to play an increasing role in the future energy system, with benefits in terms of greenhouse gas emissions, energy security and rural development.

Status of Renewable Energy - World Wide

PV Solar Installed Capacity (GW) World-Wide (2000 - 2012)



Solar PV

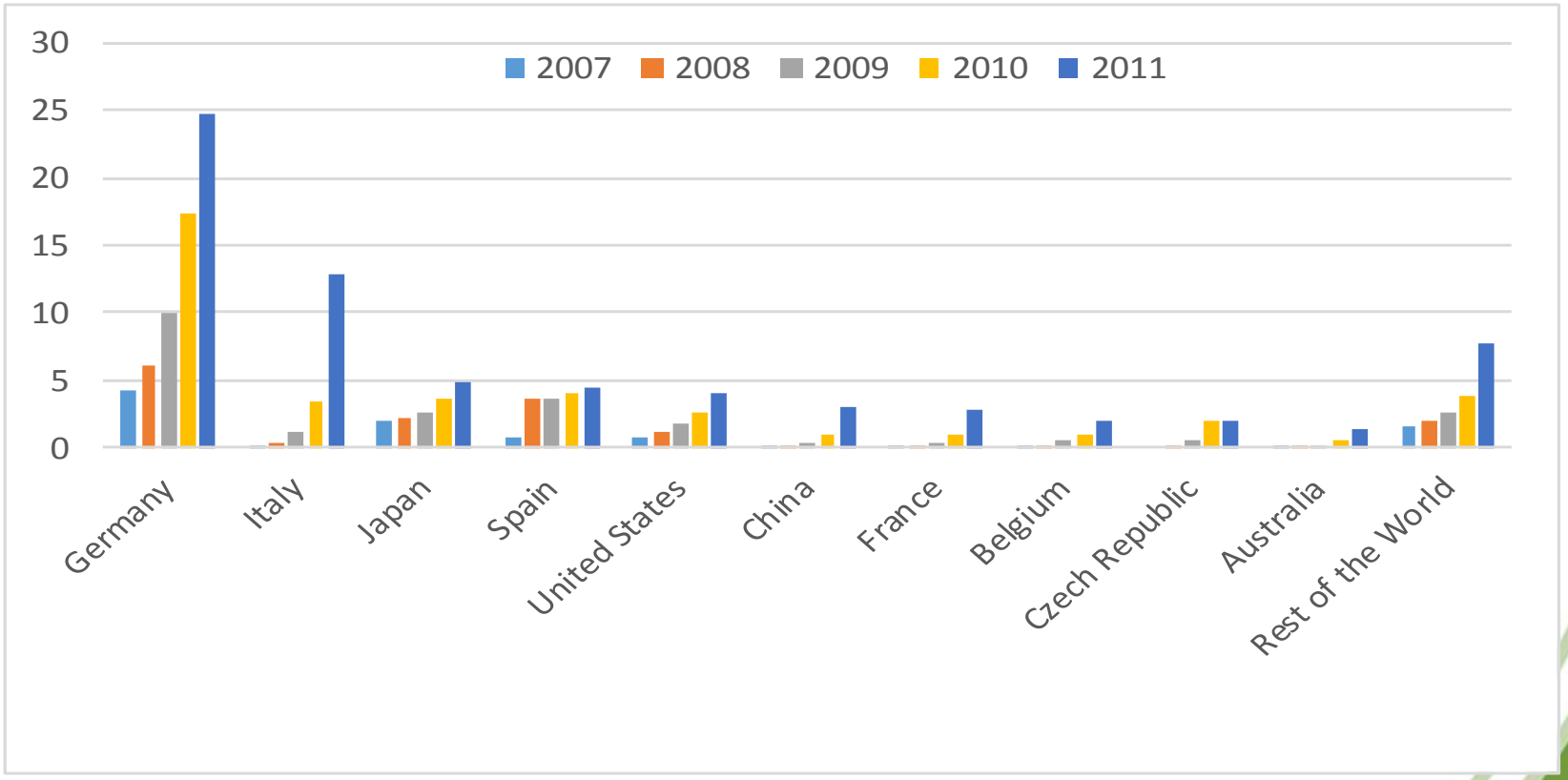
- Solar photovoltaic (PV) production has been increasing by an average of more than 20% each year since 2002, making it a fast-growing energy technology.
- While wind is often cited as the fastest growing energy source, since 2007, PV has been increasing at about twice the rate of wind - an average of 60%/year, due to the reduction in cost. In 5 yrs. From 10GW to 100GW.
- At the end of 2011 the photovoltaic (PV) capacity world-wide was 70 GW, a 75% annual increase.
- By the end of 2012 the PV capacity was more than 100GW i.e. about 40% increase.

Solar PV in 2012

“No one would have predicted even 10 years ago that we would see 100 GW of solar PV capacity in the world by 2012"

- There is an important shift towards a more global PV market, with
  - 13 GW of PV installed outside Europe (about 8 GW in 2011)
  - 17 GW in Europe (22 GW in 2011)
- Top 3 European PV markets in 2012 were Germany (7.6 GW), Italy (3.3 GW) and France (1.2 GW).
- Top three non-European markets were China (4.0 GW), US (3.2 GW) and Japan (2.5 GW).

Solar PV Operating Capacity in GW (Top 10 Countries), 2007-11



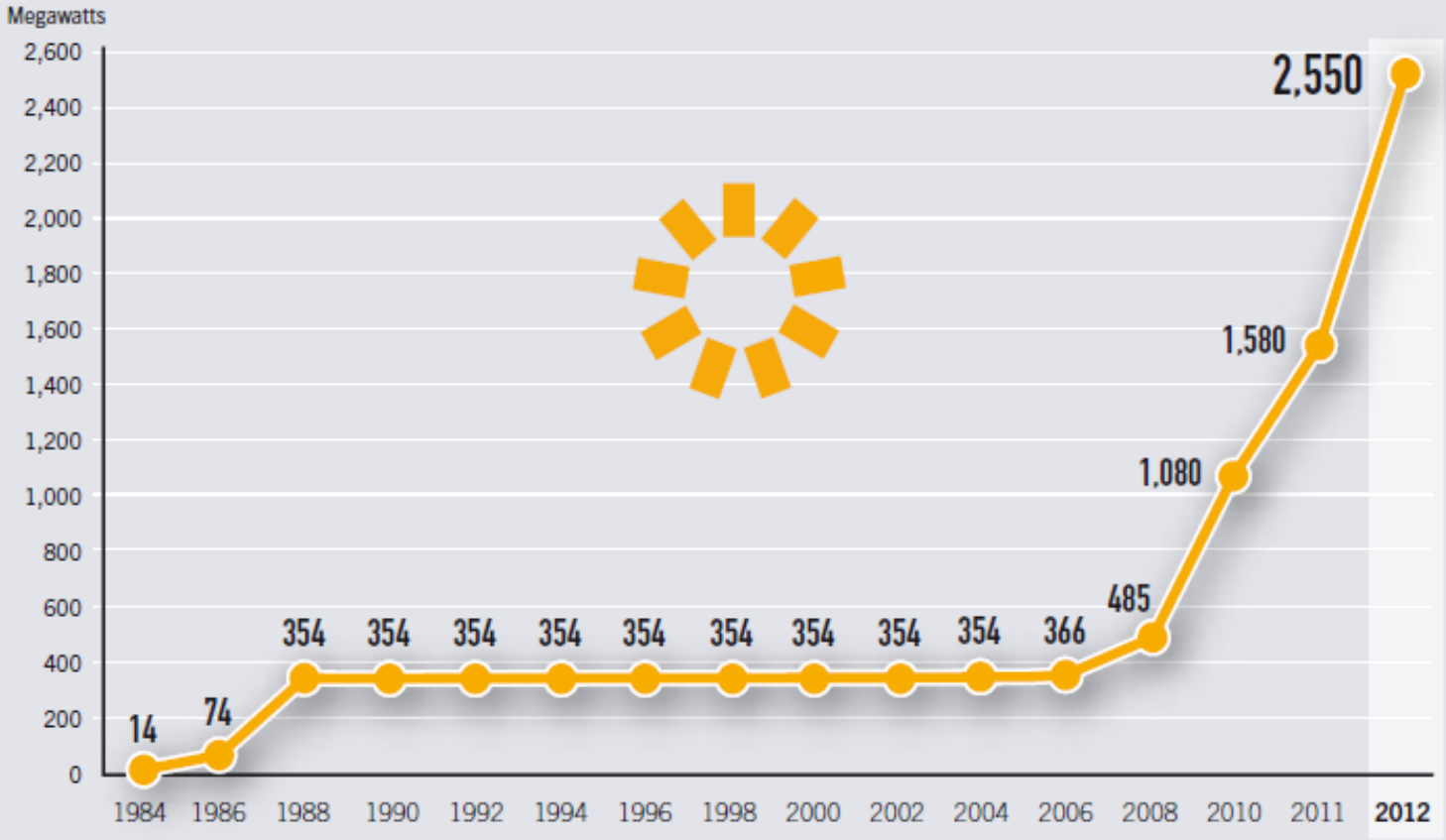
PV CAPACITY (GW) IN TOP 6 COUNTRIES, 2007-2012

Country	2007	2008	2009	2010	2011	2012
Germany	4.2	6.1	9.9	17.3	24.8	32.4
Italy	0.1	0.4	1.1	3.5	12.8	16.4
Japan	1.9	2.1	2.6	3.6	4.9	6.6
Spain	0.8	3.6	3.7	4.1	4.5	5.1
US	0.8	1.2	1.7	2.5	4.0	7.2
China	0.1	0.2	0.3	0.9	3.1	7.0

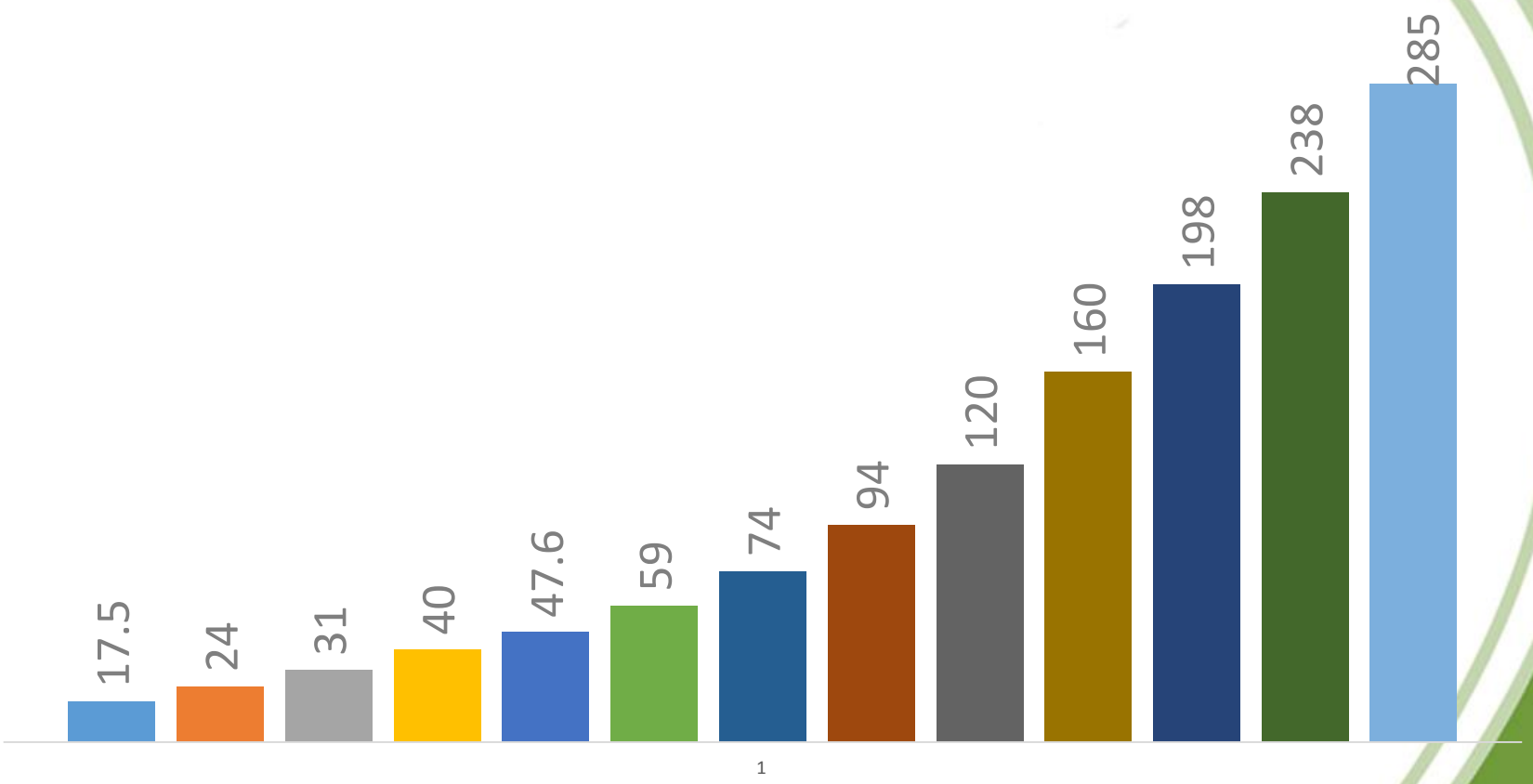
Solar CSP

- During 2011, more than 450 MW of CSP was installed.
- Over the five-year period of 2006–2011, total global capacity grew at an average annual rate of almost 35% to nearly 1,760 MW.
- Most of the world's CSP capacity is in Spain.
- Elsewhere around the world at least 100 MW of capacity was in operation at year's end. Egypt brought 20 MW on line at the end of 2010, as did Morocco (20 MW); and Algeria (25 MW).
- CSP is expected to accelerate internationally, with projects under construction in several countries, including Australia (250 MW), China (50 MW), India (470 MW), and Turkey (100 MW)

FIGURE 14. CONCENTRATING SOLAR THERMAL POWER GLOBAL CAPACITY, 1984-2012

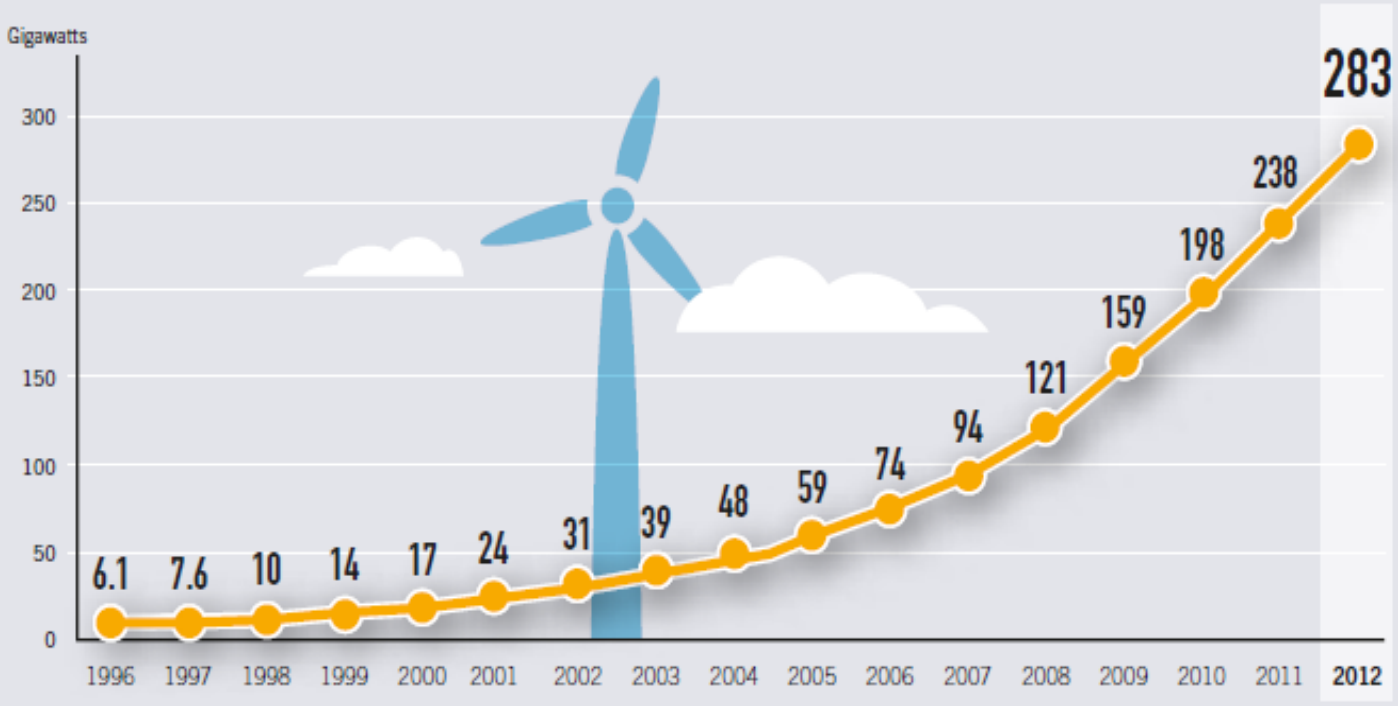


Wind Installed Capacity (GW) World-Wide (2000 - 2012)



WIND POWER

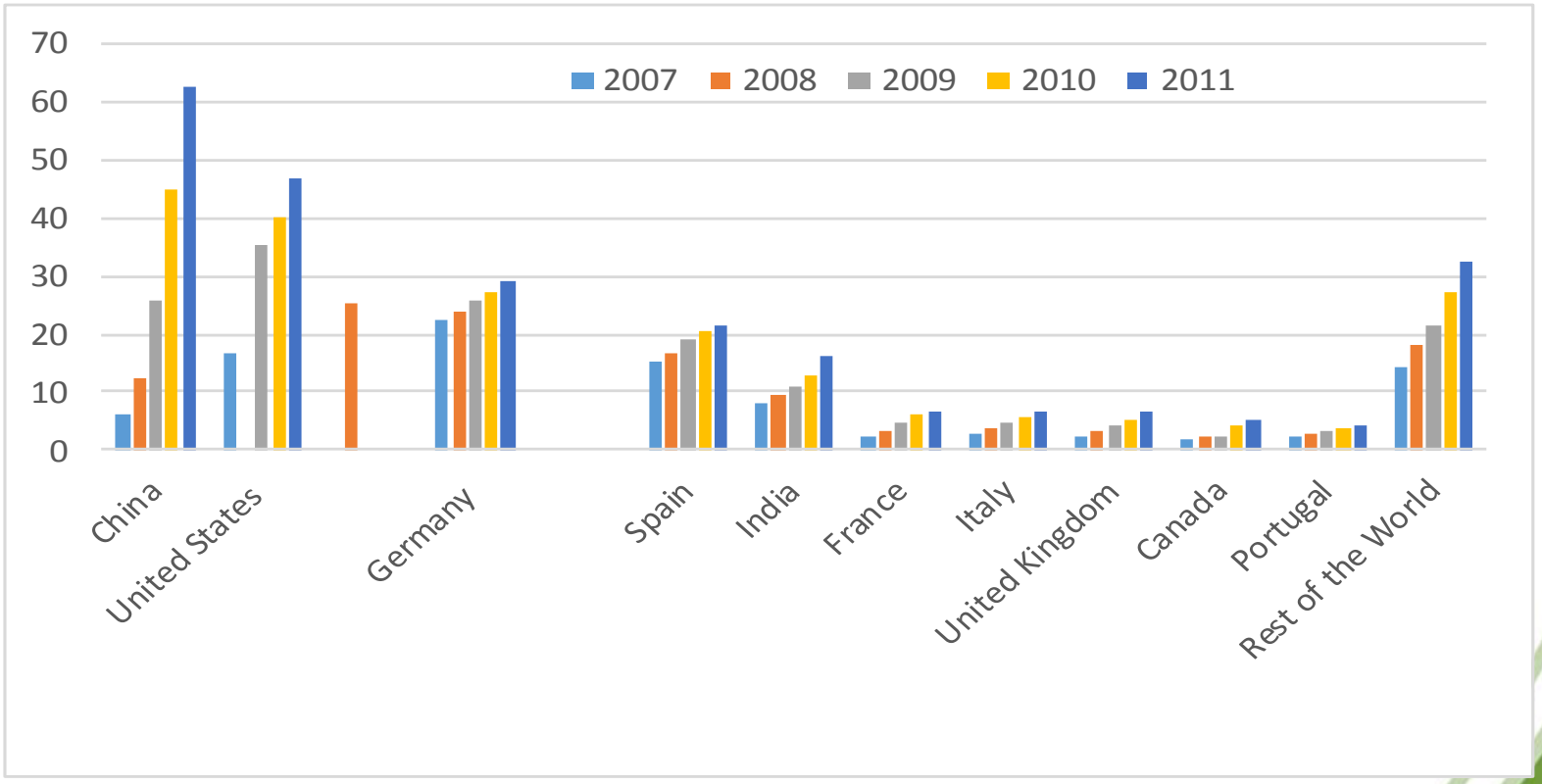
FIGURE 18. WIND POWER GLOBAL CAPACITY, 1996-2012



Wind Energy

- During 2011, an estimated 40 GW of wind power capacity was put into operation, more than any other renewable technology, increasing global wind capacity by 20% to approximately 238 GW.
- During 2012, about 45 GW of Wind power was added increasing total wind installed capacity to 283GW.
- About 83 countries around the world are using wind power on a commercial basis. At least 68 countries have more than 10 MW capacity, with 22 of these more than 1 GW.

Wind Operating Capacity in GW (Top 10 Countries), 2007-11



WIND CAPACITY (GW) IN TOP 6 COUNTRIES, 2007-2012

Country	2007	2008	2009	2010	2011	2012
China	5.91	12.21	26.01	44.73	62.73	75.3
US	16.86	25.17	35.16	40.30	46.92	60.0
Germany	22.25	23.90	25.78	27.19	29.06	31.3
Spain	15.14	16.74	19.15	20.62	21.67	22.7
India	7.85	9.59	10.92	13.06	16.08	18.4
France	2.48	3.43	4.52	5.97	6.80	7.6
Italy	2.73	3.54	4.85	5.80	6.75	7.1
UK	2.39	3.29	4.09	5.25	6.54	8.4
Canada	1.85	2.37	2.55	4.01	5.27	6.2
Portugal	2.13	2.86	3.36	3.71	4.08	4.2

FIGURE 19. WIND POWER CAPACITY AND ADDITIONS, TOP 10 COUNTRIES, 2012

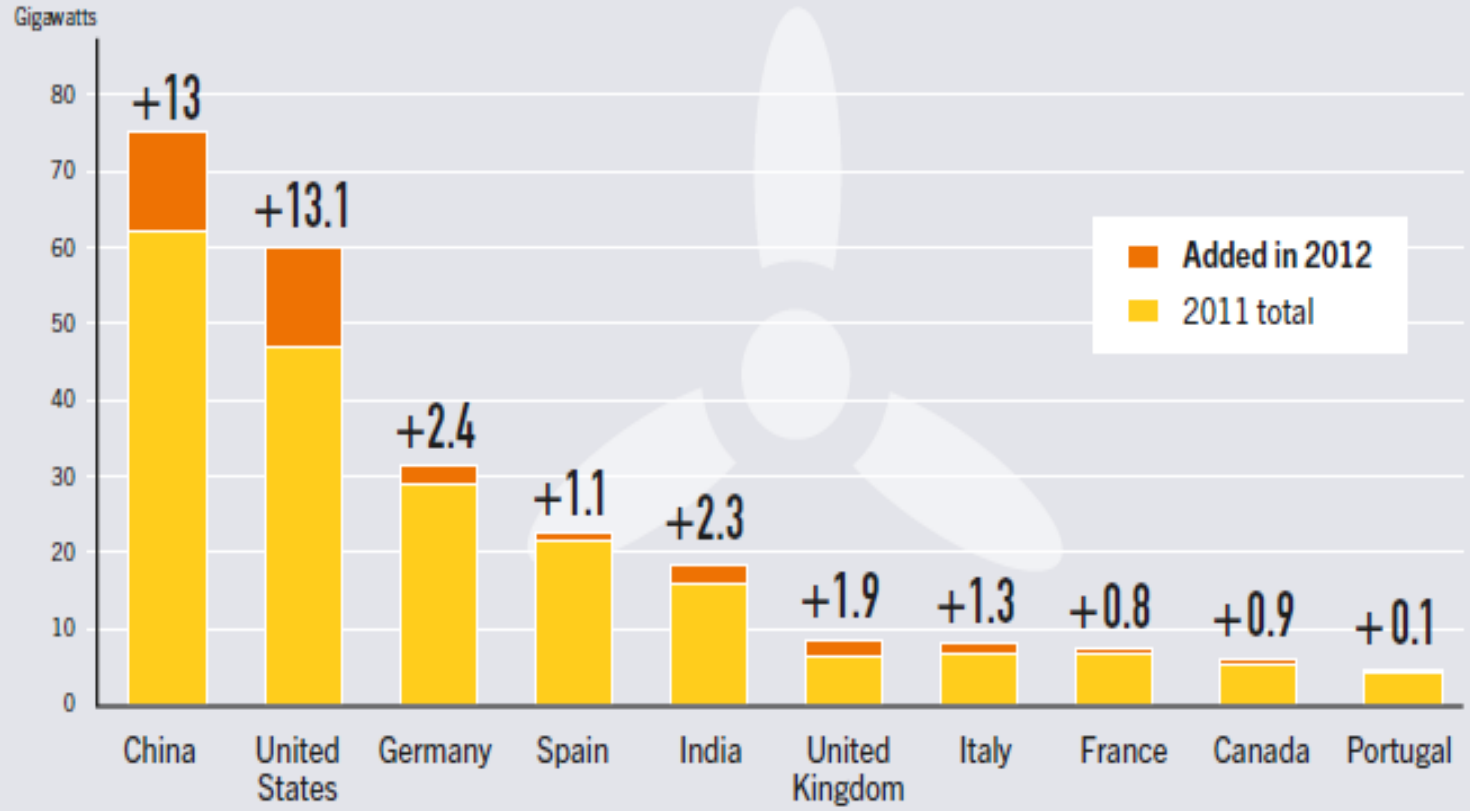


TABLE R8. WIND POWER GLOBAL CAPACITY AND ADDITIONS, TOP 10 COUNTRIES, 2012

Country	Total End-2011	Added 2012	Total End-2012
	(GW)		
China[1]	45.1/62.4	15.8/13	60.8/75.3
United States	46.9	13.1	60.0
Germany	29.1	2.4	31.3
Spain	21.7	1.1	22.8
India	16.1	2.3	18.4
United Kingdom	6.6	1.9	8.4
Italy	6.9	1.3	8.1
France	6.8	0.8	7.6
Canada	5.3	0.9	6.2
Portugal	4.4	0.1	4.5
World Total	**238**	**45**	**283**

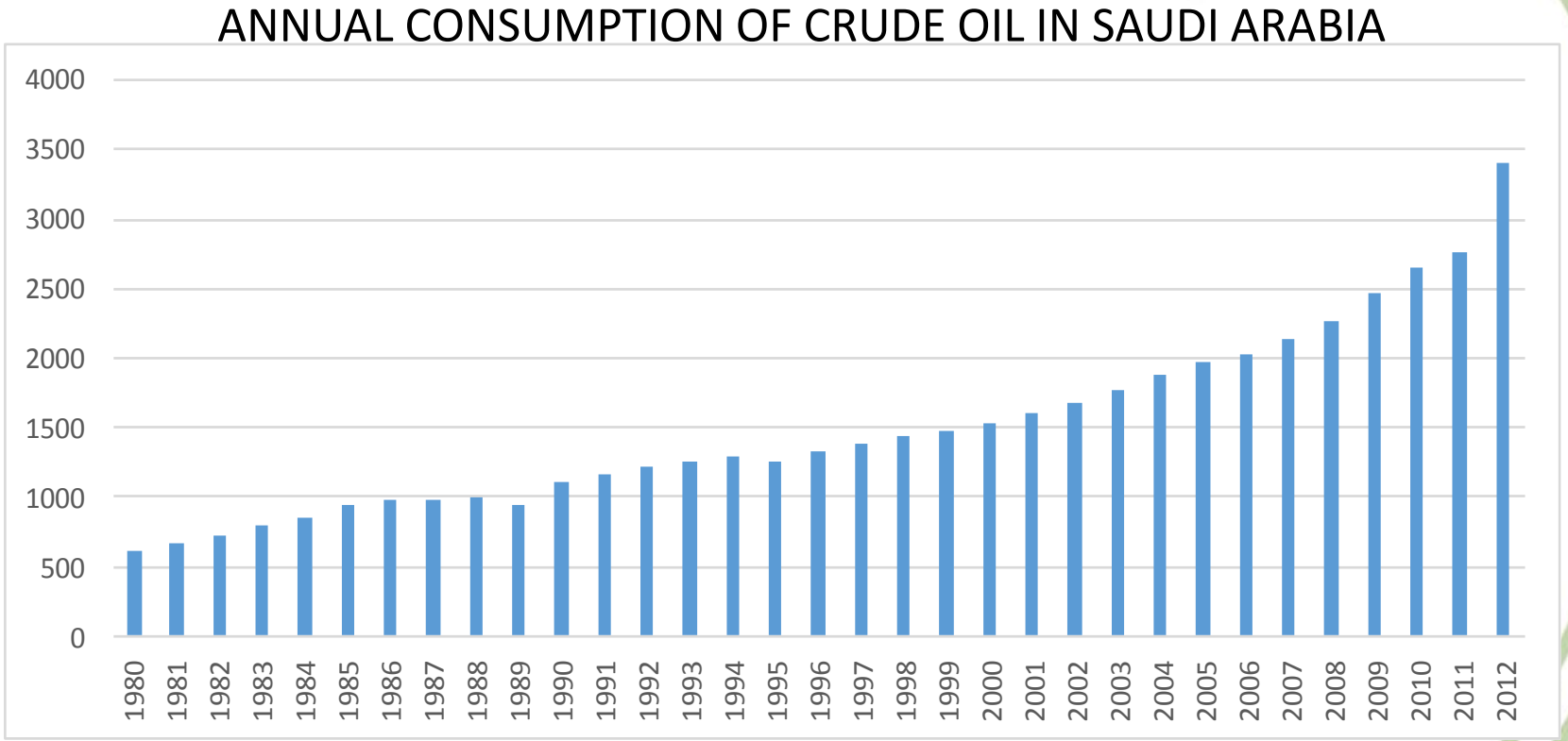
PV Solar & Wind Energy Trends (World Wide)

Recent years have seen a major scale up of wind and solar

Year	2008	2009	2010	2011	2012
PV	15.7	23	40	70	>100
Wind	120	160	198	238	285

Status of Renewable Energy in GCC

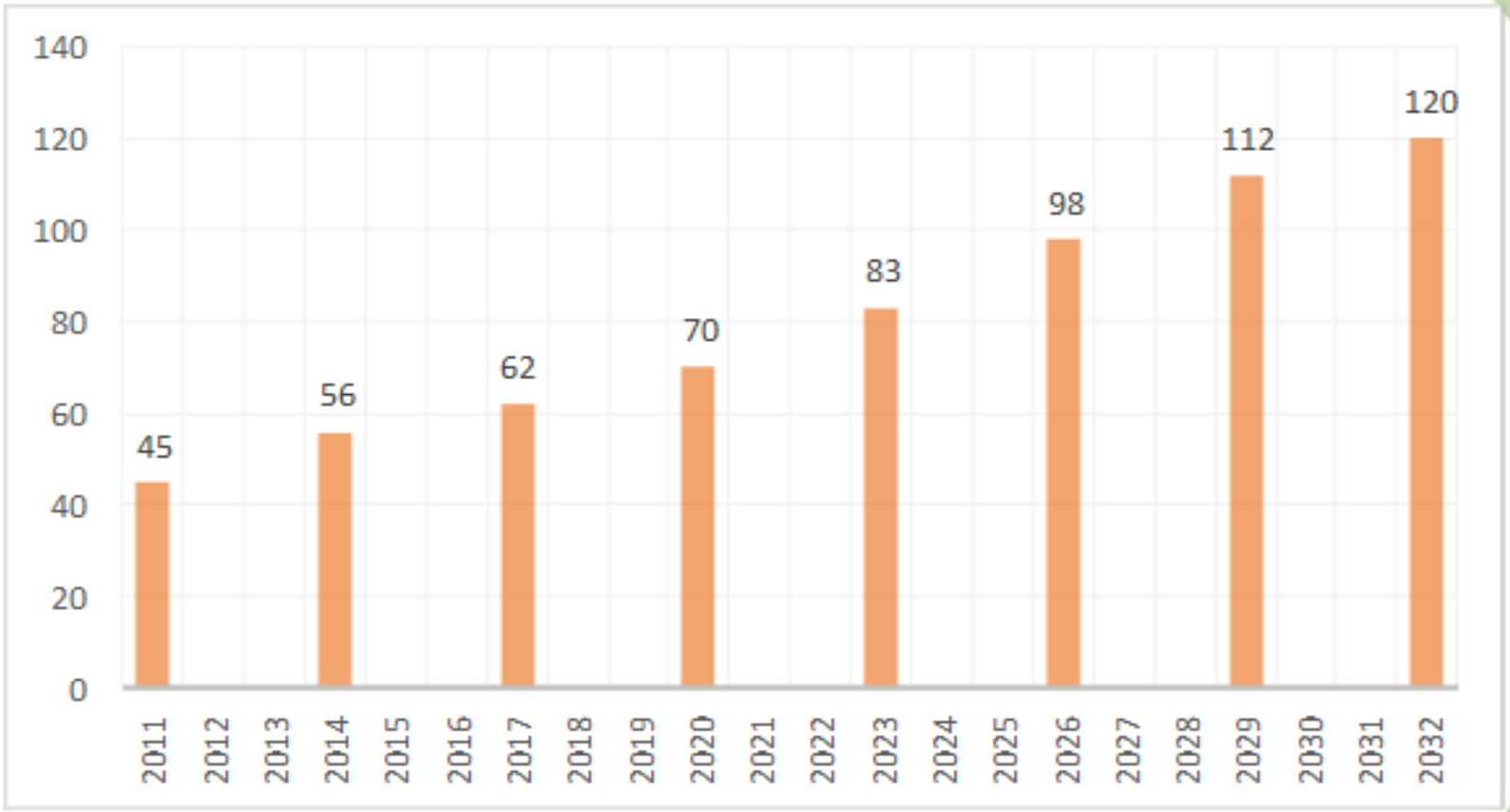
Domestic Oil Consumption



Consumption of Oil VS Energy Demand

The current domestic oil consumption is about one-fourth of the production. If this growth continues, it will have major impact on oil export. Saudi Arabia depends on oil export for 80 to 90% of its annual revenue. Current generating capacity of KSA is about 50 GW which, based on current projections, will increase to 120 GW by 2032, creating a demand for new sources of electricity to add about 70 GW of power generation capacity within next two decades.

KSA PEAK DEMAND FORECAST (GW)



Renewable Energy Projects In KSA

Projects/Plants	Power	Status
1. KAUST Solar roof-top PV	2MW	Completed
2. KAPSARC-Aramco Solar PV	3.5MW	Completed
3. KAPSARC-Aramco Solar PV extension in 3.5 MW plant	1.8MW	Under Construction (started in June 2013)
4. Aramco PV at Park Office Complex Parking Dharan	10MW	Completion in 2013
5. Farasan Solar Thermal	0.5MW	Completed in Oct, 2011
6. KACST Solar Power Desalination Plant	30,000 m^3/day	To be completed by the end of 2013
7. KACARE Solar PV Plant	2000MW	Bidding in 2013
8. KACARE Solar PV Plant	2500MW	Bidding in 2014

Renewable Energy Projects In United Arab Emirates

1. Masdar Institute roof	1MW	Completed
2. Solar PV Park	10MW	Completed
3. Floating Solar Island	1MW	Completed
4. Solar Roof Program	500MW	Under-Construction
5. Shams 1 Solar CSP	100MW	Under-Construction
6. Noor 1 Solar PV	100MW	Planned
7. Dubai Solar Park	10MW	Completion in 2013
8. Two wind energy plants	30MW each	Planned

Renewable Energy Projects in Some Other GCC Countries

Oman	1. Solar PV demonstrator	12MW	Completed
	2. Solar CSP project	50-200MW	Planned
	3. Solar thermal oil recovery	7MW	Planned
	4. Biofuel date palm factory	900 million m^3/day	Planned
	5. Solar Power Desalination	144 million m^3/day	Planned
Kuwait	1. Solar PV	1250MW	Planned
	2. Wind Turbine	10MW	Under-Construction
	3. Solar Combined-cycle Gas	60MW	Planned
Bahrain	1. Concentrated Solar Power	500MW	Planned
	2. Two "hybrid" solar-wind	5MW each	Planned
Qatar	1. Biomass	40MW	Completed
	2. Solar Power PV Plant	100MW	Planned

Future Plans of KSA in RE

Future Plans of KSA in RE

To meet the increasing energy demand, KSA has made a clear commitment to generate power from renewable and nuclear energy sources. In April, 2010, a landmark decision was taken through a royal decree for establishing KACARE. Its mandate is to make atomic and renewable energy an integral part of the energy mix in the kingdom. KACARE has announced its plans to turn Kingdom of Saudi Arabia into “Kingdom of Sustainable Energy”.

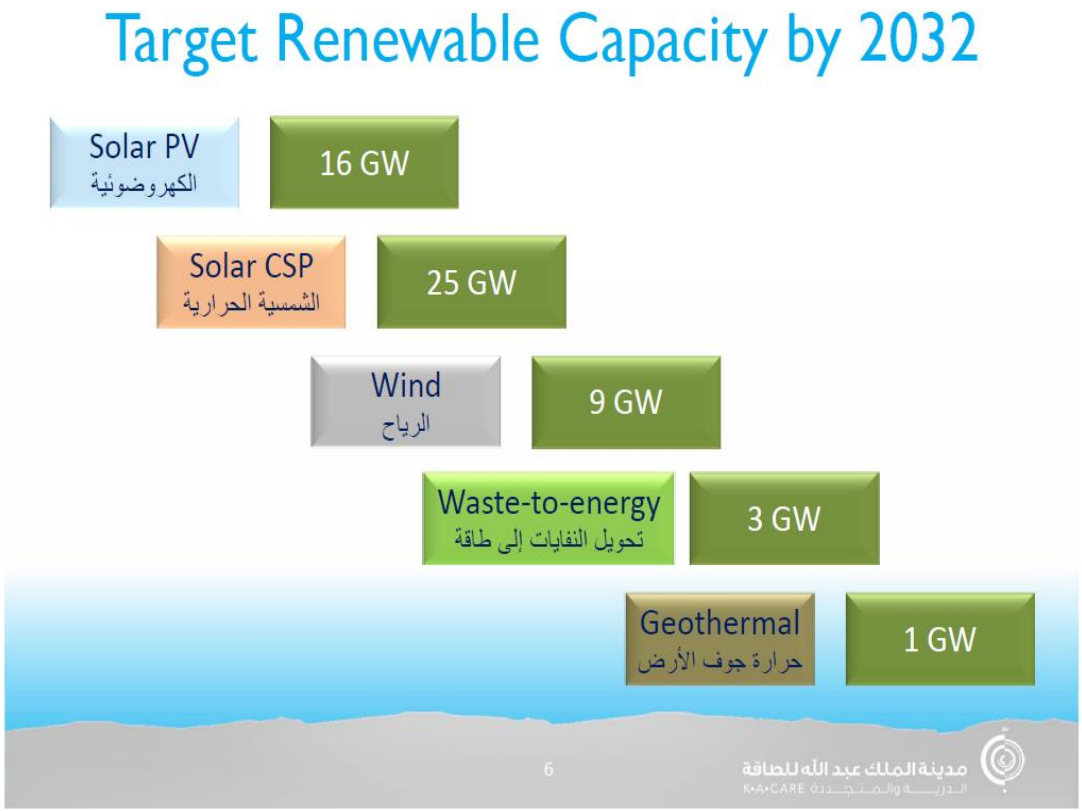
Future Plans of Kingdom

- It plans to build 41GW of solar capacity (16 GW PV and 25 GW CSP) over the next two decades, sharing about 30% of Kingdom's total electricity demand in 2032.
- Setting renewable energy targets indicate that KSA is becoming more focused to implement the alternate energy policies.
- The renewable energy will reduce the domestic oil consumption 523,000 barrels of oil per day over the next 20 years.
- RE will enable the KSA to divert its oil to export markets rather than local consumption, which will provide more revenue for the nation.

Future Plans of Kingdom

The current installed solar capacity in Saudi Arabia does not come close to some of the world's big solar farms many of which are generating 100MW or more. KSA has a long way to go to meet its goal of installing 41 GW of solar over the next two decades. It plans to start its first tender for 2000 MW of solar energy in 2013 and a second tender for 2500 MW in 2014.

Future Plans of KSA in RE

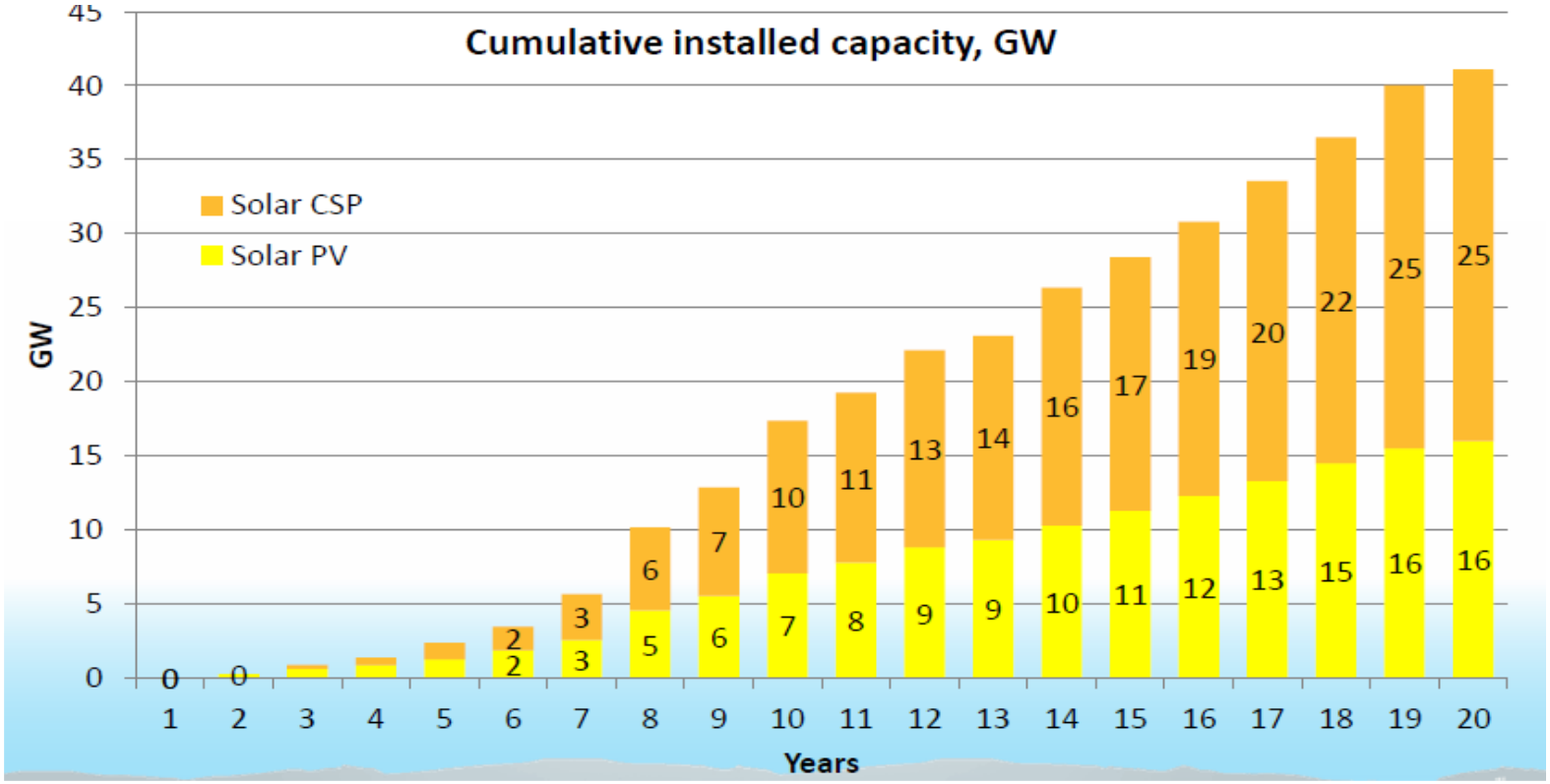


Target Capacity by 2032

Optimizing Energy Generation with Alternative Energy Economic Sector Development

Nuclear	17 GW
Renewable	54 GW

Plans of KACARE for Next Two Decades in Saudi Arabia (Solar)



Alternative Energy Deployment Roadmap

مدينة الملك عبد الله للطاقة
الذرية والمتجددة K·A·CARE

Procurement is designed to allow for multiple technologies and winners

مدينة الملك عبد الله للطاقة الذرية والمتجددة
K•A•CARE

Indicative Size of Procurement Rounds

Solar PV
1,100 MW 1st round [11-55]
1,300 MW 2nd round [15-65]

CSP
900 MW 1st round [5-25]
1,200 MW 2nd round [7-30]

Wind
650 MW 1st round [10-30]
1,050 MW 2nd round [15-50]

Other (incl. geothermal, waste)
200 MW 1st round [5-10]
250 MW 2nd round [5-15]

Note: [ ] reflect indicative number of projects

- **Initial procurement round launched in 2012** with the issuance of the draft RFP in Q3 and final RFP in Q1 2013
- Followed by **second round in 2013/2014**

Rationale for Size of Initial Rounds

First two procurement rounds could account for several thousand megawatts each

- Consistent with K•A•CARE **energy targets.**
- Consistent with **grid integration capacities** and **bids processing capabilities.**
- Sufficient enough to allow for **economies of scale** and **attract interest.**
- Gives the **possibility to select large and smaller projects** at the same time.
- But small enough to **allow for learning.**

Amounts procured are expected to increase in later rounds

- Issues resulting from the novelty of the technologies are overcome.
- A successful program sees rising participation.
- Procurement staff becomes more experienced.

Human Capacity Building

KSA aims to generate 6 GW of solar power by 2020.

About 1 GW to be installed every year.

It means 10,000 solar panels/day.

The availability of skilled people may limit the growth and success of future plans. The plans will require a substantial number of energy professionals.

Establishment of SET Center

- After policy decision, the planning for capacity building starts; to ensure that the trained human resource for the implementation of RE systems would be available.
- Such planning would help to build confidence that the Kingdom is ready to proceed with the targeted energy projects.
- In this regard, KSU and KA-CARE has agreed to promote research, training and development in sustainable energy technologies.
- Consequently, Sustainable Energy Technologies (SET) Center was established at KSU. In fall 2011, MS (RE) was launched at SET to develop human resource and competency in RE that will be required for the successful deployment of energy projects.

MS Renewable Energy Program at SET Center

Critical Mass of Human Capital

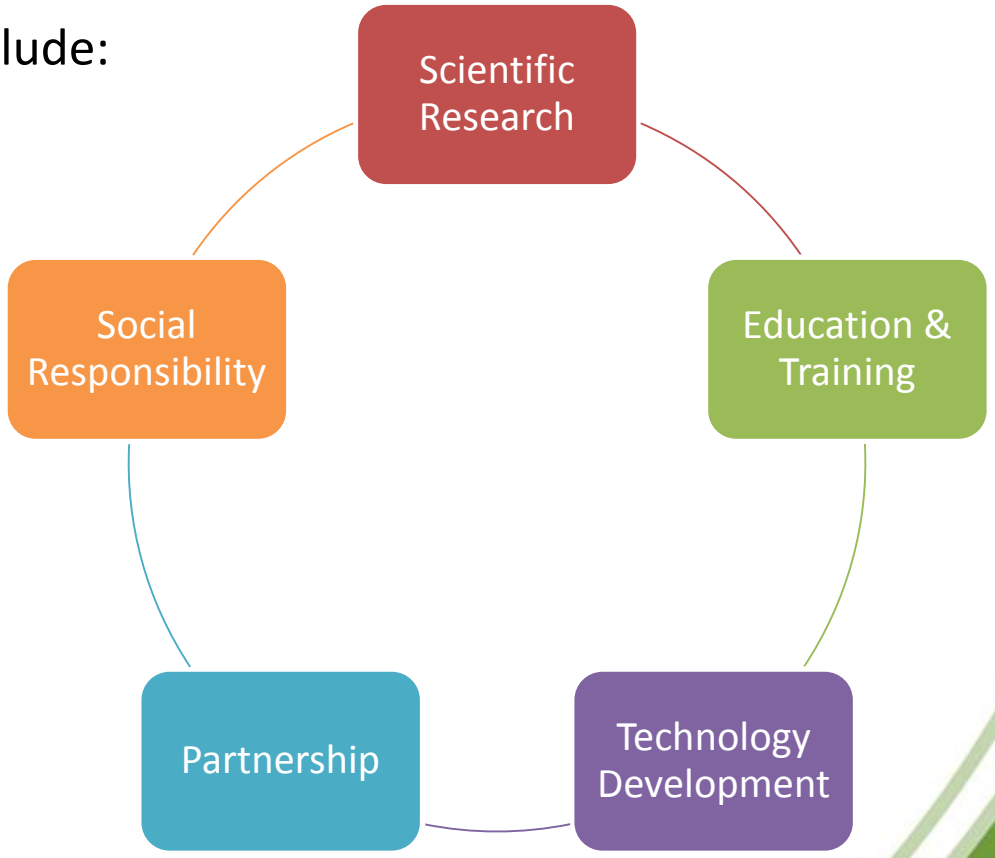
Sufficient human resources with up to date knowledge and expertise of the latest renewable energy technology developments must be available.

SET center is established for the purpose of conducting research and providing education and training in SET.

Establishment of SET Center

Sustainable Energy Technologies (SET) Center was established as a program in fall 2010. It was upgraded to a center in Feb. 2012.

The objectives of SET include:



Objectives of SET Center

- Performing research in the field of sustainable energy technologies.
- Participating in the development of innovative sustainable energy technologies in alignment with the national strategic plans.
- Preparing the qualified manpower in the field of sustainable energy through education and training program.
- Providing consultation and technical support in sustainable energy projects and initiatives.
- Promoting the culture of sustainable energy through social responsibility programs.

Objective of Academic Program

The main objective of the academic program at SET Center is to develop human resource and competency in renewable energy technologies that would be required for successful implementation of sustainable energy plans in the Kingdom.

Masters Program at SET

MS program in renewable energy is in progress at the since fall 2011. The program is multidisciplinary and a joint venture of five departments:

- Chemical Engineering
- Electrical Engineering
- Mechanical Engineering
- Physics
- Chemistry

Admission Requirements

- B.Sc. degree in one of the following areas: Chemical, Electrical, Mechanical, Chemistry or Physics
- A GPA of at least 3.00 on a scale of 4.00 or equivalent.
- A minimum TOEFL score of 500 on PBT, 61 on IBT or the IELTS band score of 6.0. Minimum score in GRE Quantitative must be 500 (144 in new scale)
- At least three letters of recommendation from the faculty who taught the applicant at university-level.
- Official transcripts and degree certificates for final admission.

Financial Support

A student at KSU may have following financial benefits during his graduate studies:

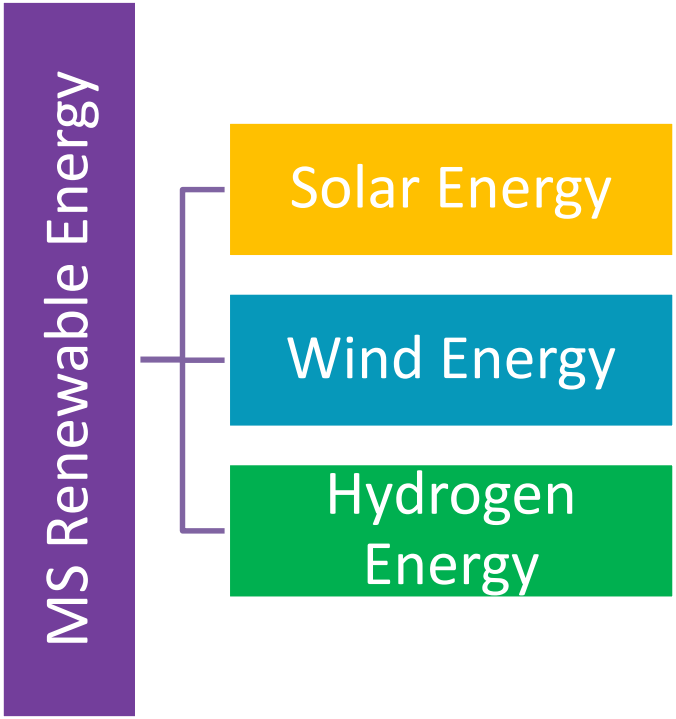
- Free tuition.
- A monthly Scholarship of 890 SR
- Free furnished air conditioned bachelor housing.
- Medical and dental coverage at KSU hospitals.
- Subsidized meals in the University cafeteria.
- A chance to participate with the faculty in funded Research Projects
- Air ticket to Riyadh on joining and annual return ticket to home country.

Degree Requirements

Successful completion of 31 credit hours of graduate courses and a research thesis:

- 13 credits of core courses
- 9 credits of specialized courses
- 3 credits of elective courses
- 6 credits of dissertation

Program Structure



Students can shape the program according to their needs and interests, choosing from the following specialization:

- Solar Energy Technology.
- Wind Energy Technology.
- Hydrogen Energy Technology

Basic Core Courses

- Renewable Energy 1 – Solar Energy
- Renewable Energy 2 – Wind, Hydrogen & other Energies
- Energy Conversion and Storage
- Heat Transfer and Thermodynamics
- Seminar

Specialized Courses

- Solar Energy Technology.
- Wind Energy Technology.
- Hydrogen Energy Technology

Solar Energy Technology

- Solar Thermal Technology
- Solar Cooling
- Solar Active Heating Systems
- Solar Cell and Module Technology
- Advanced Solar Cells Designs
- Photovoltaic Systems Technology

- Design and Fabrication of Solar Cells
- Power Semiconductor Converters
- Design and Applications of PV Systems

Wind Energy Technology

- Wind Turbine Aerodynamics
- Design & Control of Wind Turbines
- Wind Farm Technology
- Technologies for Wind Generation
- Power Semiconductor Converters

Hydrogen Energy Technology

- Hydrogen Production
- Hydrogen Storage
- Selected Topics in Hydrogen Technology
- Fuel Cells
- Materials Characterization