TAMPEREEN TEKNILLINEN YLIOPISTO

Vision of the power system in 2035

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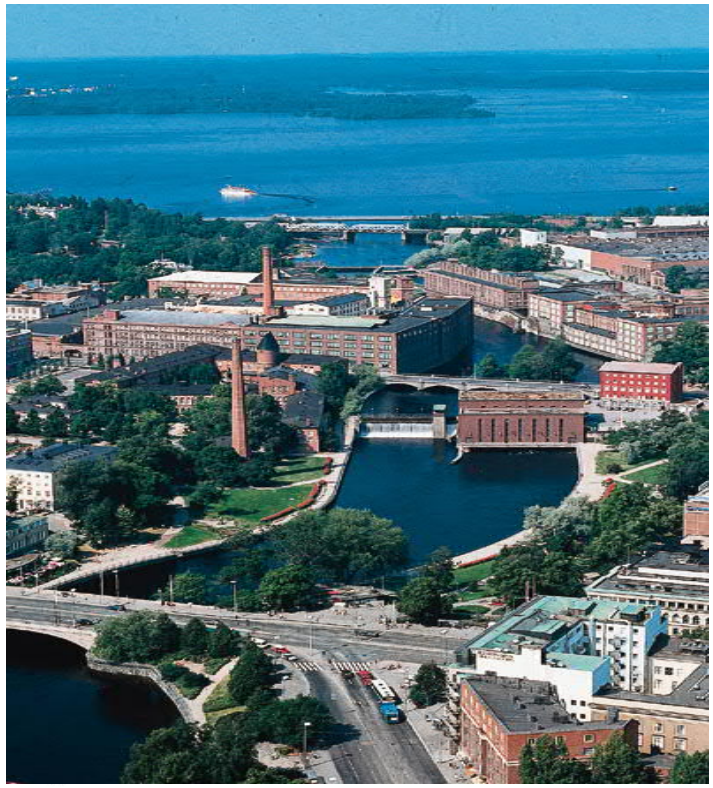

TAMPERE UNIVERSITY OF TECHNOLOGY

- Established in 1965
- 7900 students and 1600 employees, including 1700 international students + employees from 80 countries

- Research combines natural sciences, fields of engineering and business to strengthen export industry of Finland
- Key research areas

✓ Digital operating environment
✓ Energy- and eco-efficiency
✓ Health technology
✓ Light-based technologies

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Target of the training

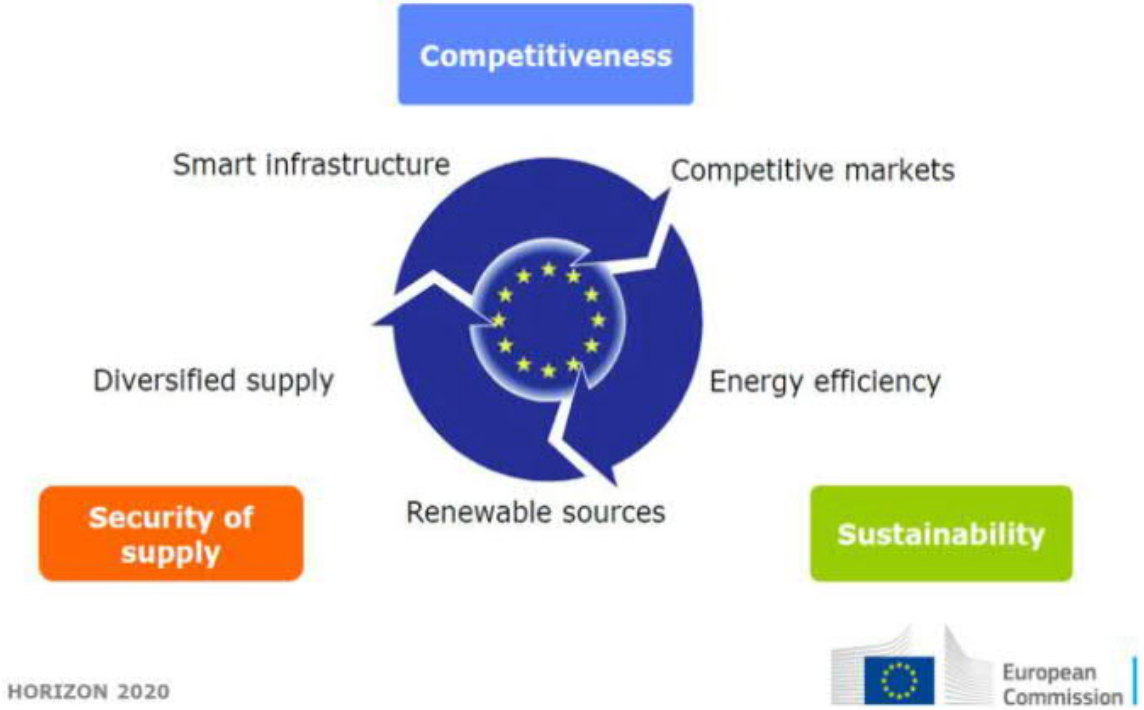
- The objective of the training is to create a vision of the future power system in Laos.
- The conventional power system will change toward the so-called Smart Grid due to increased amount of renewable power generation, electric vehicles, improved ICT devices etc.
- People are more dependent on uninterrupted power supply. However, due to climate change the difficult weather conditions increase, e.g. strong storms and raining which cause problems to the reliable electric power supply.
- One solution might be the island operation of the grid and so called microgrids.
- The attendees discuss about the possibilities and challenges of the future power system. Finally, they will create the own vision about the future power system in Laos.

Agenda: Day 1

Time	Topic
9.00-9.45	Introduction Discussion and description of the present power system in Laos, main strengths and challenges
9.45-10	Coffee break
10-12	Changes in the future power system - Change in power production: use of renewable energy - Possibility to use energy storages (battery, water storage) - Change in power consumption: increased amount of electric home devices, electric vehicles. Energy use in industry? - Automation, remote control - Climate change: stronger wind and raining - Urbanization
12-13	Lunch
13-15	Discussions in groups about the future power system in Laos
15-15.15	Coffee break
15.15-17	Presentation of the group works and discussions

Introduction

Global changes, which affect to power system



Global changes, which affect to power system

- Urbanization
- Climate change -> changes in weather and need to use renewable energy
- Increased amount of electronic loads -> need of high power quality
- Need to improve energy efficiency
- People are dependent on uninterruptable power supply
- Customer will be active part of energy business (or automation controls activity)
- International regulation
- New business models and service business related to renewable energy
- Digitalization, automation, remote control, cyber security
- Security, safety, energy self-sufficiency
- Energy storages (battery, water storage)
- Electric vehicles
- Bio fuels
- Power electronics as a part of power system
- New protection devices and protection methods

Global changes, which affect to power system

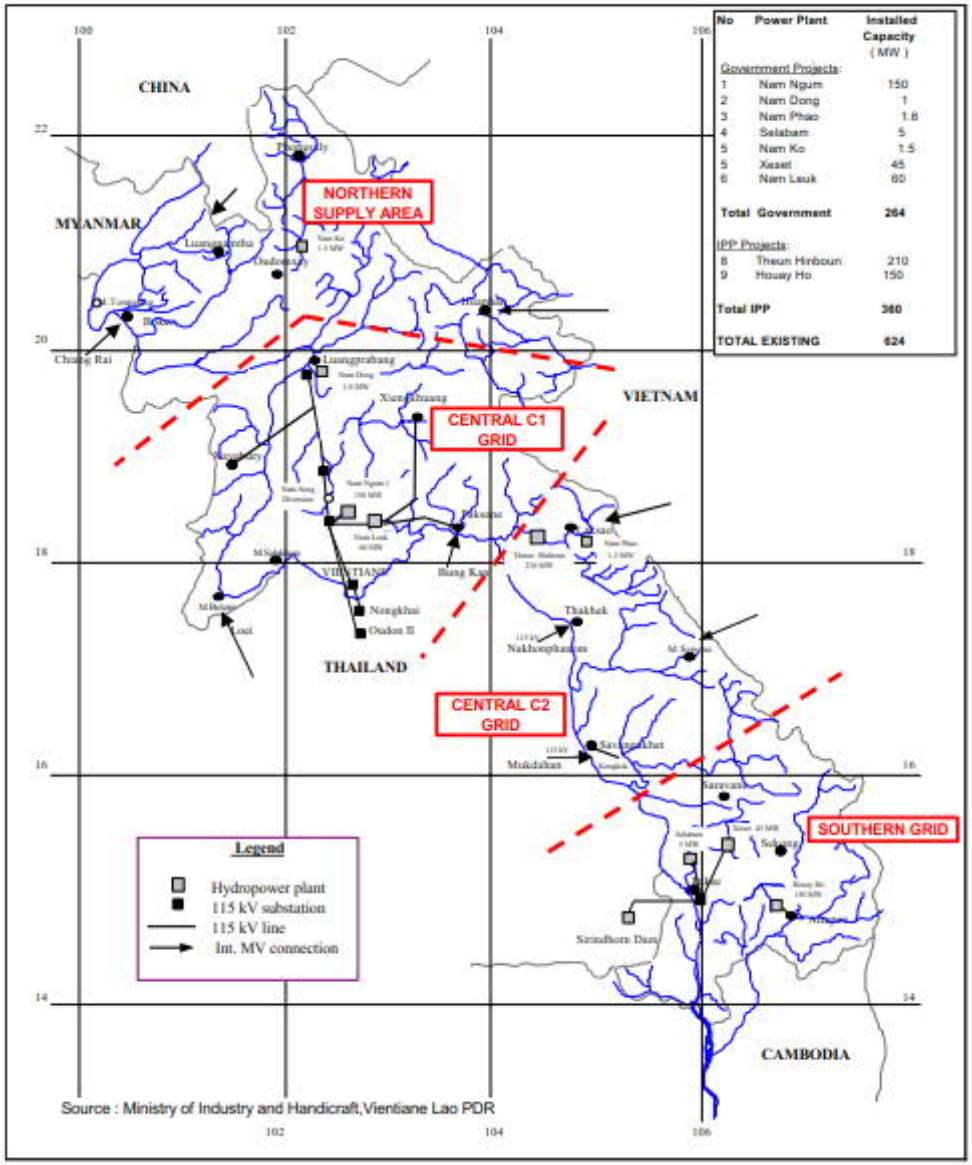
- Increase of renewable energy -> solar and wind power depends on weather, not possible to control -> power balance -> grid stability?
- Business models, services, regulation
- Small-scale renewable energy, demand response, energy storages, customer interface
- Import and export of electric energy
- Varying power production -> energy storages and demand response
- Energy market models
- Frequency control, energy reserve markets
- Nordic energy market -> European energy market -> Asian energy market?
- AMR measurement -> varying electricity price every hour
- Micro-grids, island operation

Discussion and description of the present power system in Laos, main strengths and challenges

Grid structure

- EDL operates the transmission and distribution network in the 3 regions of central, northern and southern Lao PDR.
- The Central 1 and Central 2 regions were integrated into a single region in 2011
- However, the three regions (115 kV systems) remain isolated from each other.
- In addition to the main grid operated by EDL, provincial authorities operate some 85 mini grids that are supplied by diesel generators or small-scale hydro power stations in remote areas. These facilities primarily serve remote areas that are not yet part of the national grid.
- OLD MAP

Figure 3.1: Existing EdL System (Hydro generation and 115 kV Transmission)

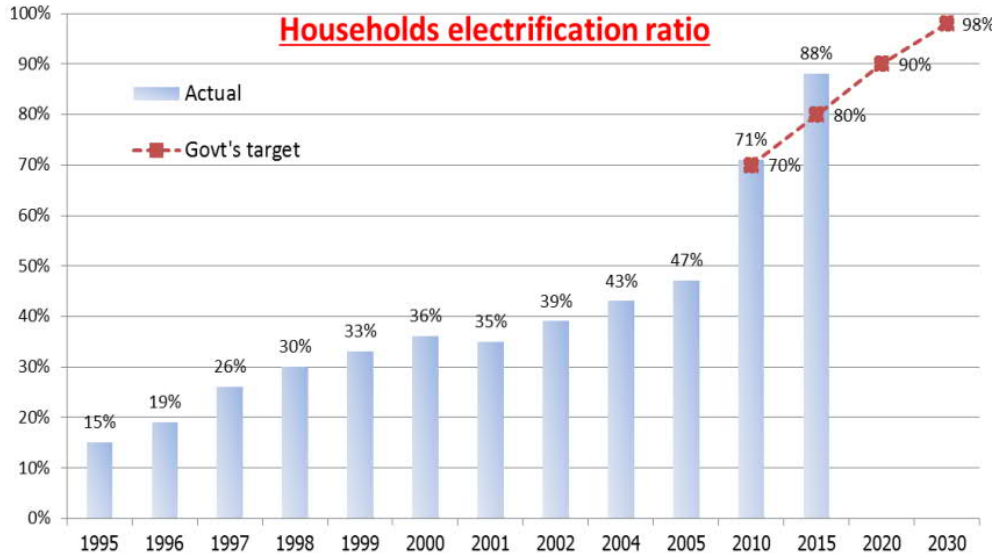


Fast electrification of all households

Table 7.1: Household and Village Electrification Ratio Targets

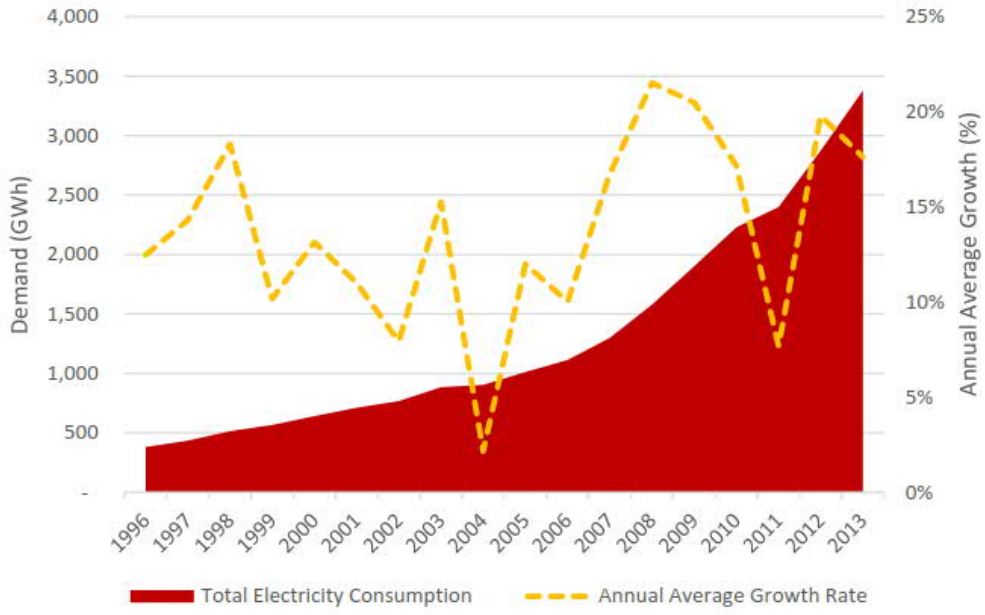
Year	Villages	Households
1999	19%	34%
2010	43%	55%
2020	80%	90%

- More than 92% of households now have electricity
- Grid extension
- Off-grid development: solar + village hydro/diesel mini grids, 150 000 household
- A rational development plan is needed to guide development to the maximum advantage of the country, and to forecast the capital investment and revenue implications of this development.



Electricity demand growth

- Domestic demand has been growing rapidly. Annual electricity consumption increase 15%/year
- Electricity consumption has been traditionally dominated by residential consumption, which made up 40%.
- Industry consumption as at 2013 accounted for 33% of total electricity consumption, will increase in the future
- Commercial sector 20 %



Source: Electricity Statistics 2013, Electricite Du Laos, 2014

Figure 27 **Lao PDR GDP Composition**

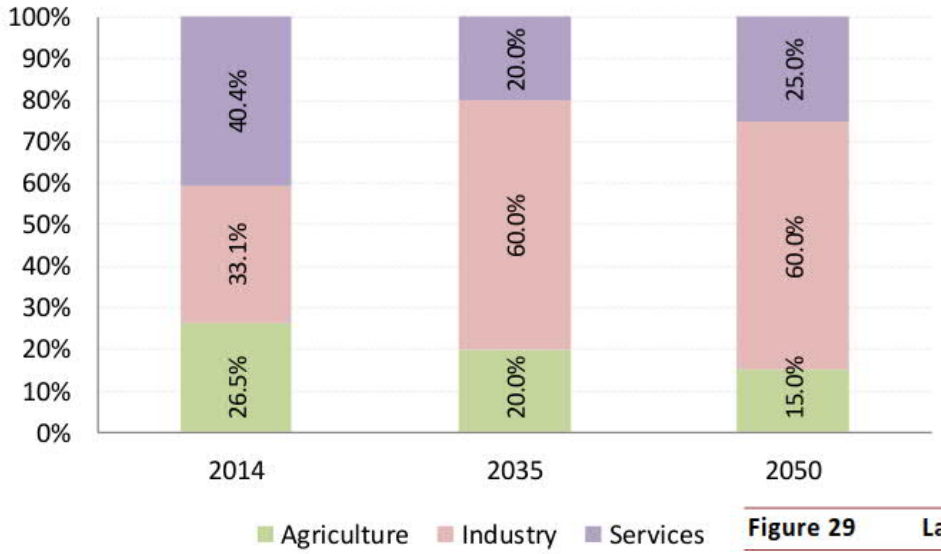
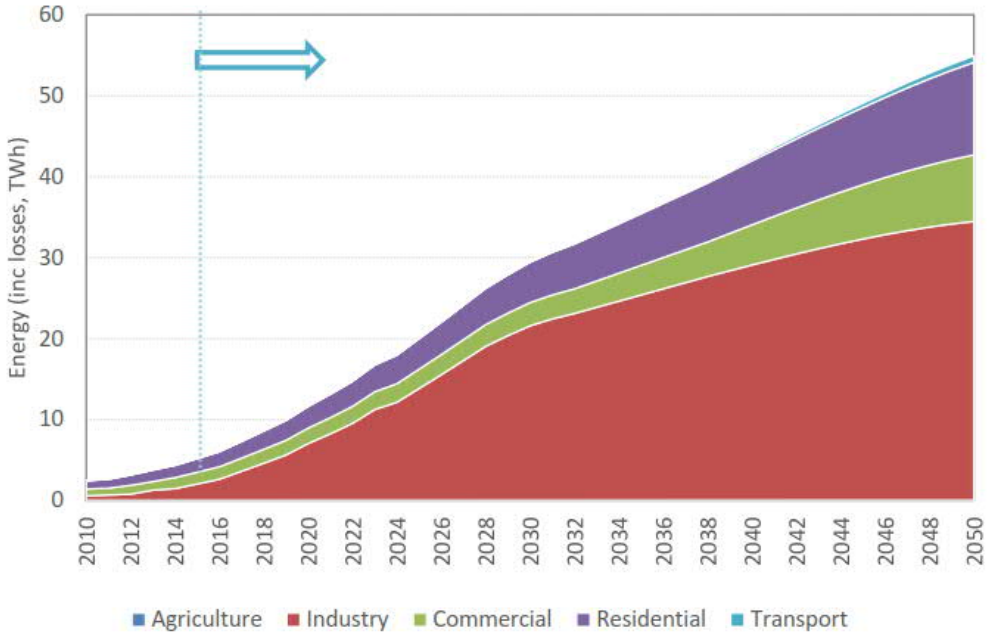
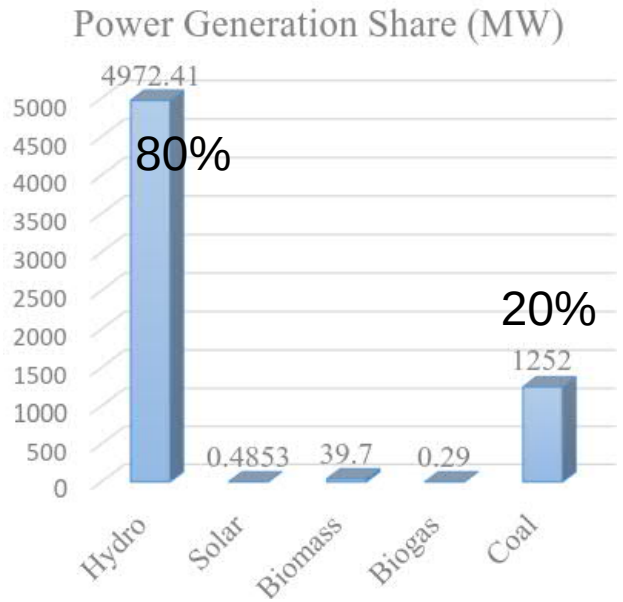


Figure 29 **Lao PDR Projected Electricity Demand (2015-50, BAU)**

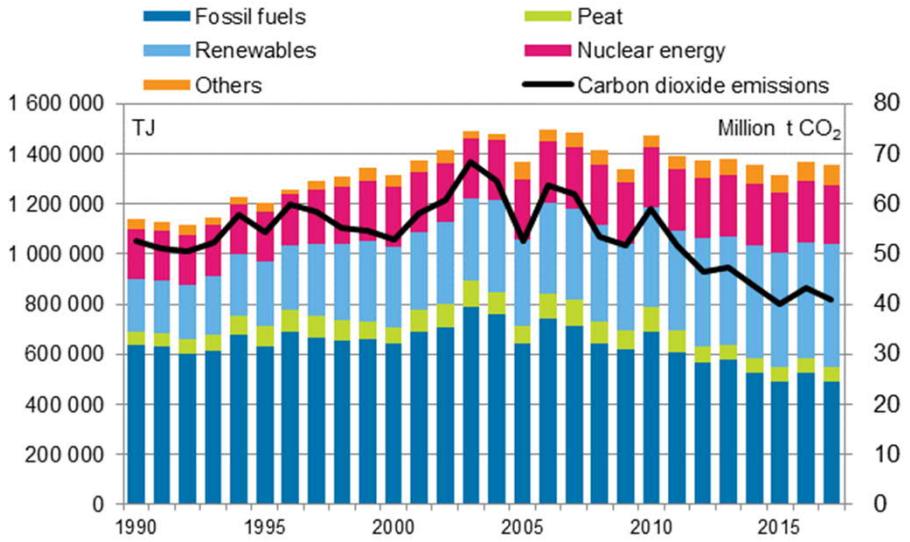


Power consumption and generation share in Laos and in Finland

- Low electric power consumption 500 kWh/person/year in Laos compared to 15 250 kWh/person/year in Finland
- High transmission and distribution power losses > 10% in Laos and 3-5 % in Finland



Laos



Finland

Figure 31 **Lao PDR Installed Capacity (BAU, MW)**

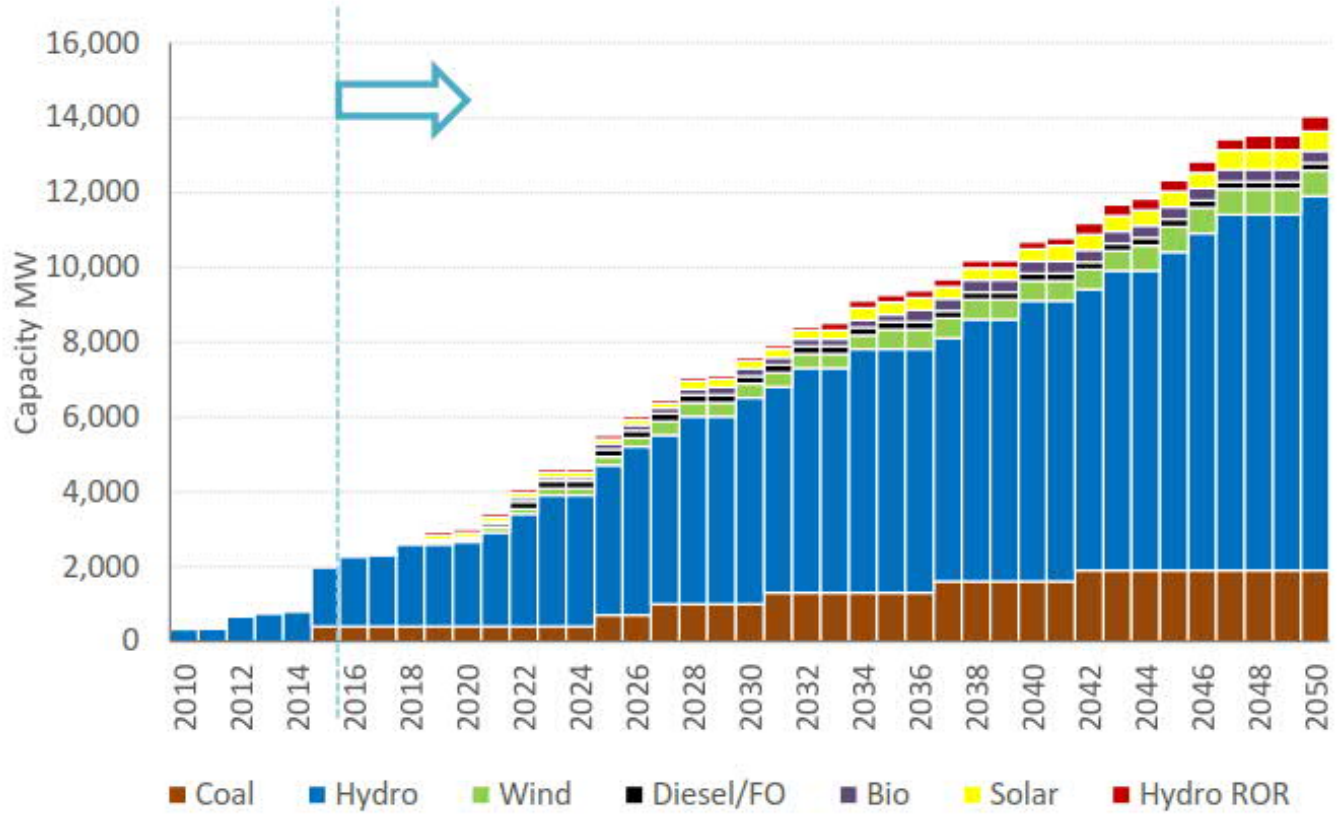
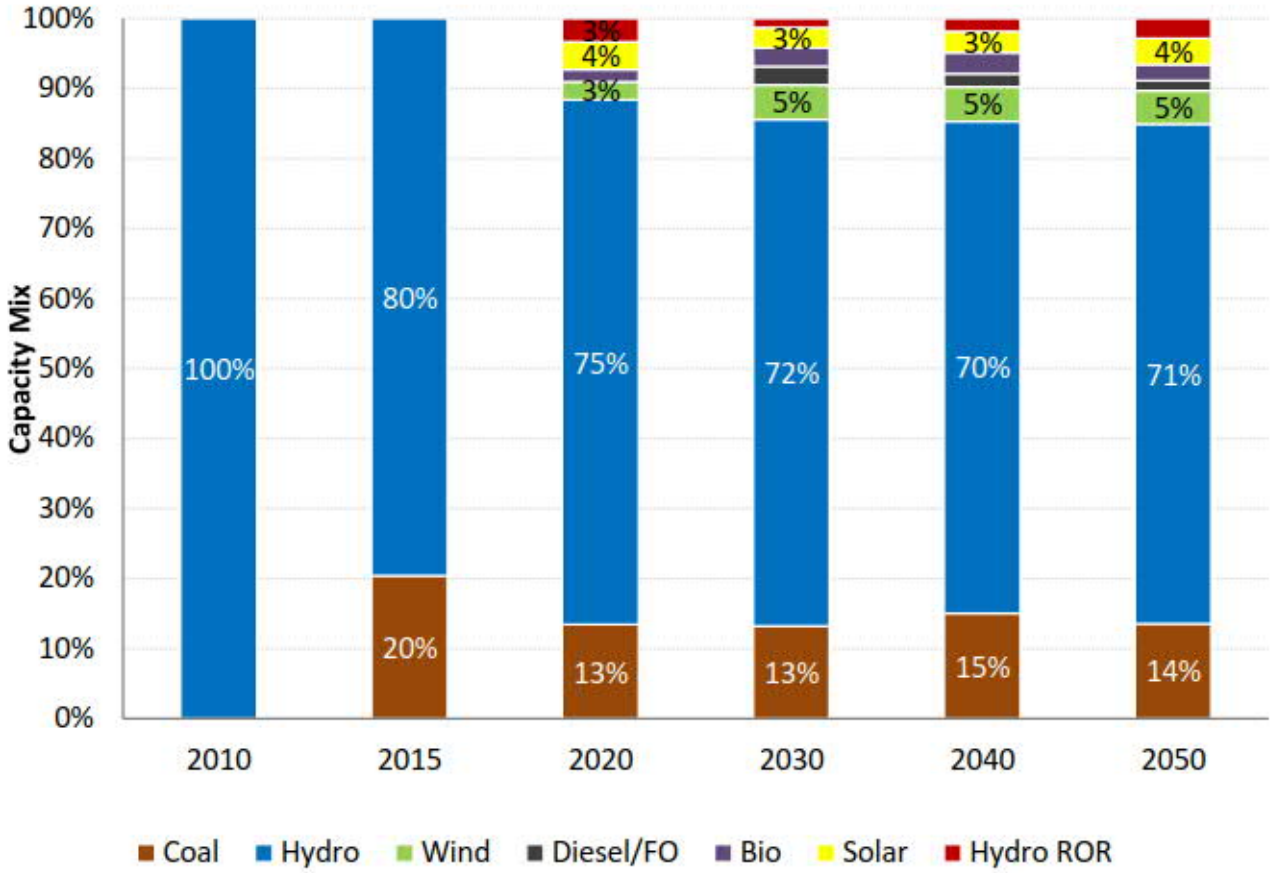


Figure 32 Lao PDR Installed Capacity Mix Percentages (BAU, %)



Export market of electrical energy

- Increase of hydropower generation capacity
- Cooperation between ASEAN/GMS countries is increasing, 500 kV **international grid interconnections** are planned, and in the longer term competitive markets may emerge.

Export and import shares

- Lao PDR exports a large amount of hydropower to Thailand, but in exchange imports electricity to supply provinces that are not connected to the national power grid.
- These demand points include copper and gold mining operations, which consume significant amounts of power.
- Lao PDR also has 4 interconnections with China, with capacity of 2,000 MW to ensure adequate power supplies in Luang Prabang and the Northern provinces.

Figure 8 **Export and Import Shares by Country (2013)**

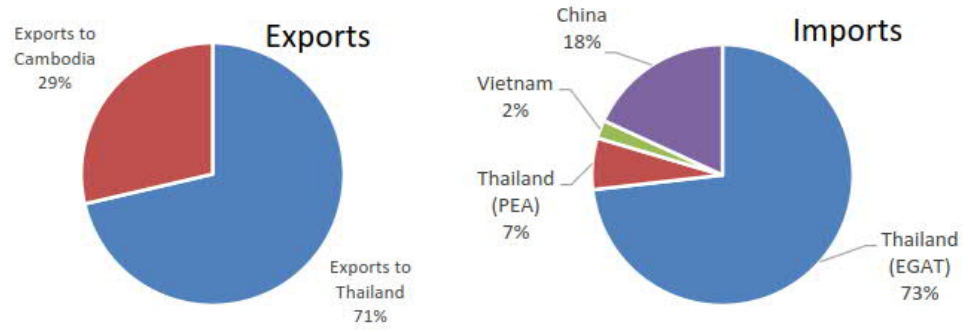


Figure 9 **Historical Annual Exports (2010-13)**

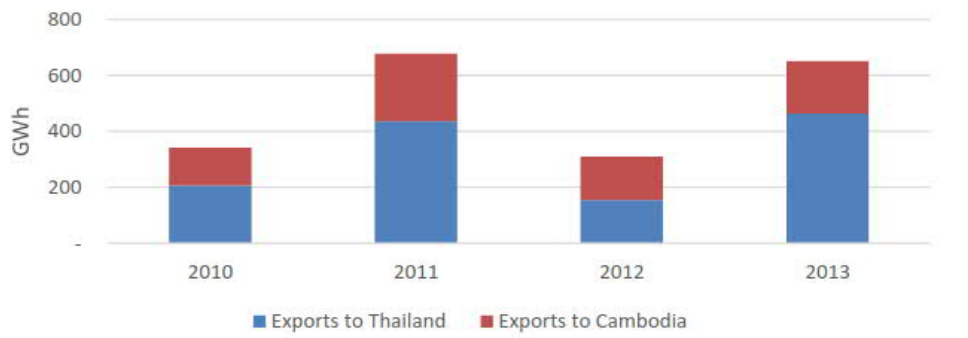
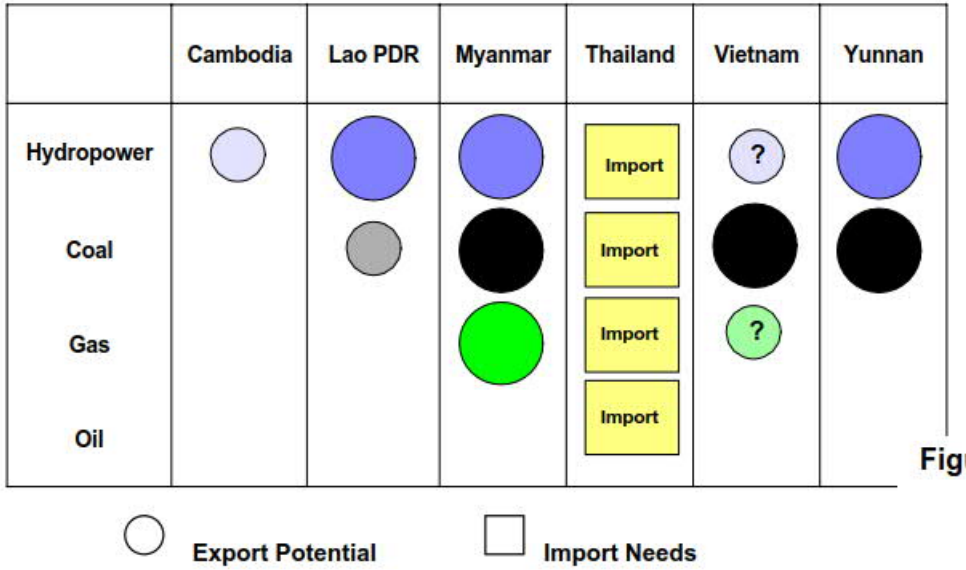
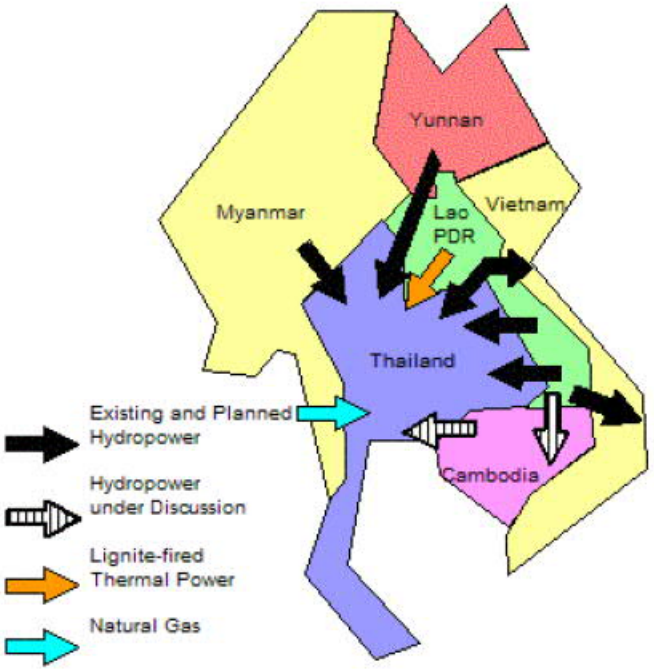


Figure 5.1: Import and Export Potential of Regional Energy Resources



Imports of around one-third of its total electricity requirements and exported 690 GWh

Figure 5.2: Energy Trading in the Greater Mekong Sub-Region



Export market of electrical energy

- Electricity exports have also soared: most of Laos' hydropower goes straight to neighboring countries.
- This development comes with significant **environmental and social risks**
- Dams can block the migrations of fish, alter a river's flow and degrade wildlife habitat.
- They can also introduce new risks to river communities; last year, for example, a dam broke along Laos' Nam Ao River, unleashing a torrent of water that flooded seven villages and ruined acres of farmland.
- The uncertainties and risks of the future – including those related to **climate change**. Changes in rainfall and extreme weather, for example, could pose a risk to Laos' hydropower-dominated electricity system.

Energy market

- Extent of private sector involvement and the private power procurement models
- **Setting of wholesale and retail tariffs** in Lao PDR and neighboring countries.
- In the longer term, establishment of a competitive power market within the region and the emergence of merchant plants.

Renewable energy

- Target to increase a share of renewable energy to 30 % in the total energy mix by 2025
- The potential role of energy resources beyond hydropower in the future?

- **Solar**

✓ Home solar systems 50-100 W
✓ 700 kW grid connected demonstration project by Japanese grant
✓ 500 MW solar farm under study, 100 MW solar and wind hybrid project
✓ 10 MW solar farm under construction

- **Wind**

✓ 600 MW under negotiation for development in Sekong province (1st phase 250 MW)
✓ 3 additional projects under field investigation, target 2 000 – 3 0000 MW

- **Biomass**

✓ 39 MW in operation, 20 MW under construction, target 1000-2500 MW

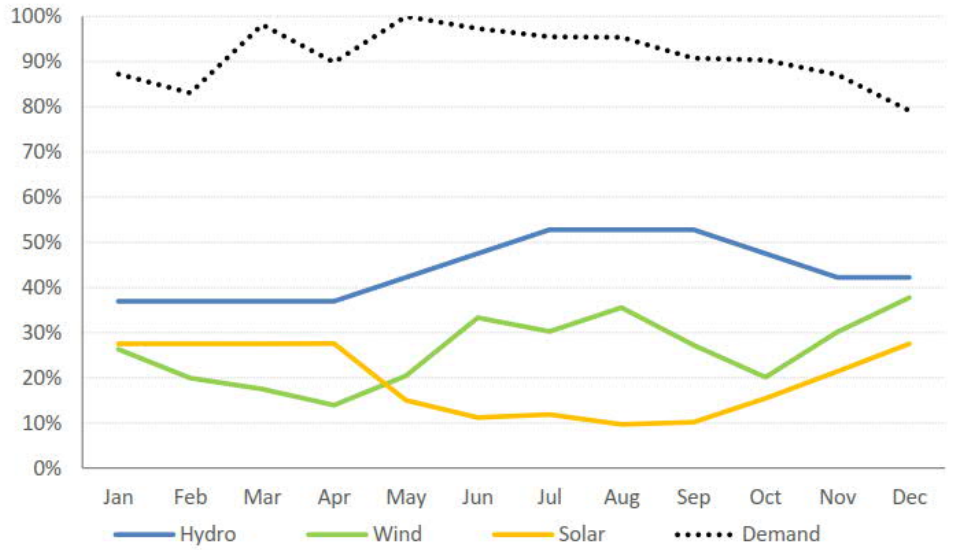
- **Biogas**

✓ 10 000 kg/day to replace the LPG import, livestock farms

Seasonality in renewable resource profiles

- There is some natural seasonal / monthly diversification between resources: demand in Lao PDR is highest peaking between March to May which coincides with reduction in wind speeds in Lao PDR.
- The solar intensity drops towards the middle of the year and wind speeds and hydro inflows start to increase.
- The greatest potential for solar lies in the central region of the country, covering the main load center of Vientiane.
- The hydro inflows fall into reservoirs, some with significant amount of storage, which enables smoothing out generation throughout the year

Figure 21 Seasonality in Renewable Resource Profiles and National Demand

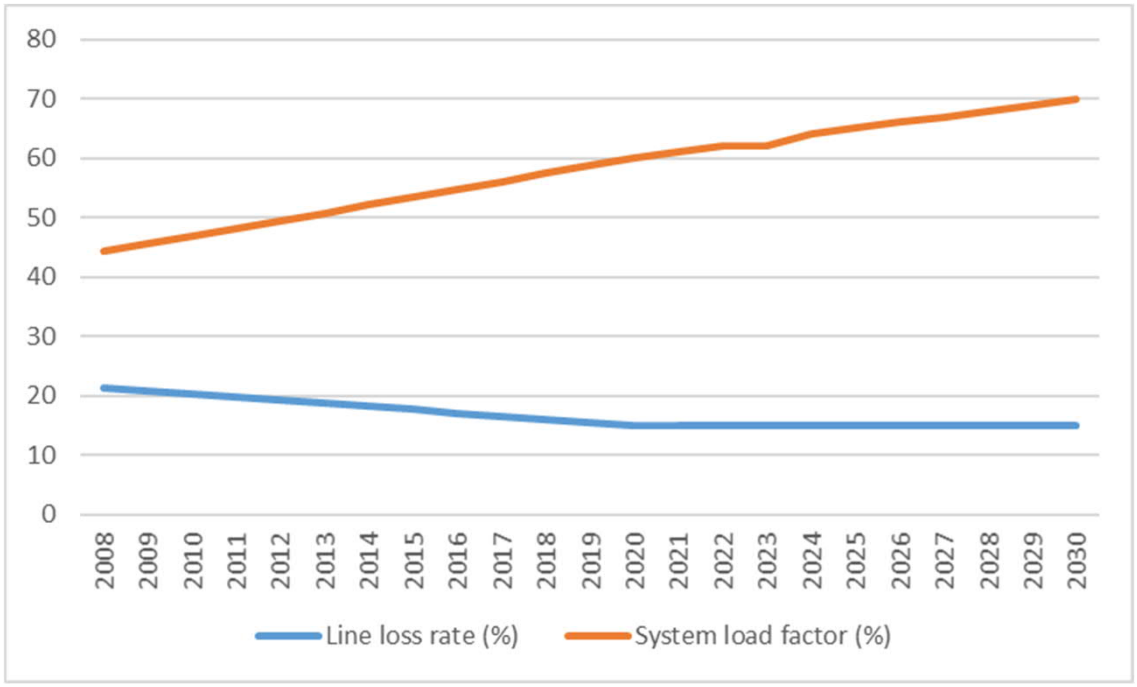


Source: Consultant analysis

Transmission and distribution losses

Table S-9.1: Transmission Line Loss for Domestic Power Supply System in Laos

Season	kW Loss [MW]	Annual Energy Loss [MWh]	Annual Energy Loss [million USD]
Dry	70	339,100	13.8
Wet	201	975,154	39.7



Targets

- Increase electrification ratio to 98 % by 2025
- Increase energy efficiency, reduce 10 % of energy consumption in 2030
- Increase energy export 12 000 MW by 2020: 7 000 MW to Thailand and 5 000 MW to Vietnam
- Reserve coal for domestic use and power generation
- Increase a share of other renewable energy to 30 % by 2025 (bio-fuel 10 %)
- Ensure energy security, sustain socio-economic development and enhance environmental and societal sustainability
  - -> financial incentive for investors (subsidies)
  - -> develop and modify legal documents (laws, regulations, guidelines)
  - -> establish renewable energy fund
  - -> financial mechanism: import duty free on production machinery, equipment, raw materials

Challenges related to renewable energy

- Lack of information on resources available and sustainability
- Capacity building among technical level and community level about renewable energy
- Geographic location, no access road during rainy season
- Limited budget
- Several renewable energy technologies have been tried in the Lao PDR, with varying experiences in terms of unit size, unit sourcing, scale of deployment, safety aspects, and ease of maintenance.
- Imported pico hydropower systems (of up to 1 kW) have flourished, even though they are not entirely safe to operate and are difficult to maintain.
- The common rule (**Grid Code**) applied to all the power system users is urgently required to be established that determines the technical requirements of connecting the EDL power system and the types of the information provided with the power system operator.

Challenges related to power system

- The electric load has grown faster than eDl could upgrade its electrical system, resulting in frequent, prolonged power outages. A major cause of the problem was that the electrical system was not automated. The only way the operators could learn of outages was when they were reported by customers; they then had to send out crews to manually find and repair them, which made for longer outages and was an inefficient use of personnel.

1. Increase system reliability— ensure a continuous and stable electrical supply
2. Minimize prolonged power outages that cause economic loss to the country.
3. Modernize the system—use the latest automation technology to maintain a modern electrical grid for the future (SCADA DMS, re-closers and pole-mounted load break switches)
4. Allow for future system expansion
5. Ensure power quality
6. Limit economic cost
7. Maximize supply security—use the latest safety and security standards to maximize the security of supply.

Main changes in the power system

Main changes in the power system

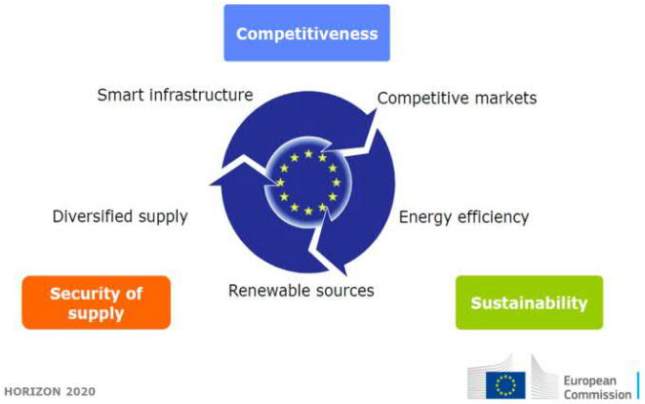
- Change in power production: use of renewable energy
- Possibility to use energy storages (battery, water storage)
- Change in power consumption: increased amount of electric home devices, electric vehicles. Energy use in industry?
- Automation, remote control
- Climate change: stronger wind and raining
- Urbanization
- Increased amount of electronic loads -> need of high power quality

Global changes, which affect to power system

- Urbanization
- Climate change -> changes in weather and need to use renewable energy
- Energy self-sufficiency
- Customer will be active part of energy business (or automation controls activity)
- International regulation
- Need to improve energy efficiency
- New business models and service business related to renewable energy
- Digitalization, cyber security
- People are dependent on uninterruptable power supply
- Security, safety
- Energy storages
- Electric vehicles
- Bio fuels
- Power electronics as a part of power system
- New protection devices and protection methods
- Microgrids

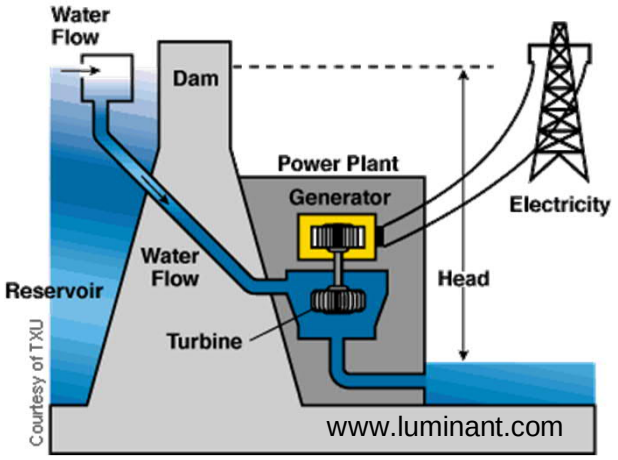
Global changes in power system

- Decreased use of fossil fuels
- Increase of renewable energy -> solar and wind power depends on weather, not possible to control -> power balance -> grid stability?
- Automation, ICT, big data, digitalization
- Business models, services, regulation
- Small-scale renewable energy, demand response, energy storages, customer interface
- Import and export of electric energy
- Closing nuclear power plants
- Varying power production -> energy storages and demand response
- Energy market models
- Frequency control, energy reserve markets
- AMR measurement
  -> varying electricity price every hour



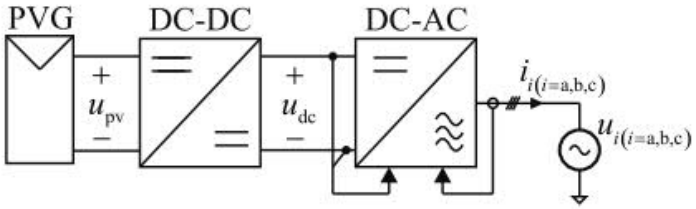
Conventional Power Generation

- Mechanical or potential energy is transformed into electrical energy by using a synchronous generator
- Frequency of the grid is determined by the synchronous generators
- No power electronics is needed in conventional power generation



Renewable Power Generation

- Power electronics is needed to interface renewable sources with the grid
- Photovoltaic power plants produce DC current -> needs to convert to DC with correct amplitude by a DC/DC converter or AC by an inverter



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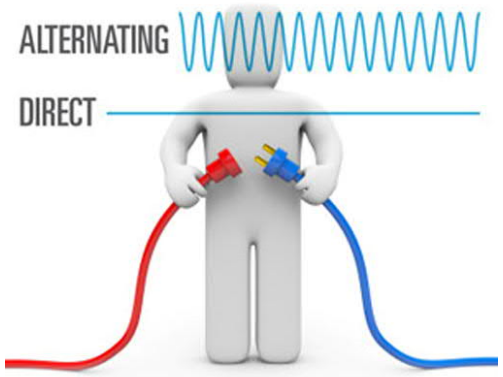

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Renewable Power Generation

- Varying output power, not possible to control
- Multiple generators connected in series + parallel -> controllability, stability?

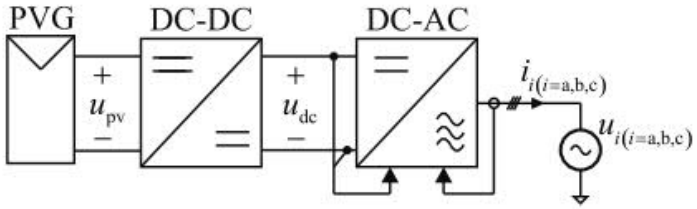

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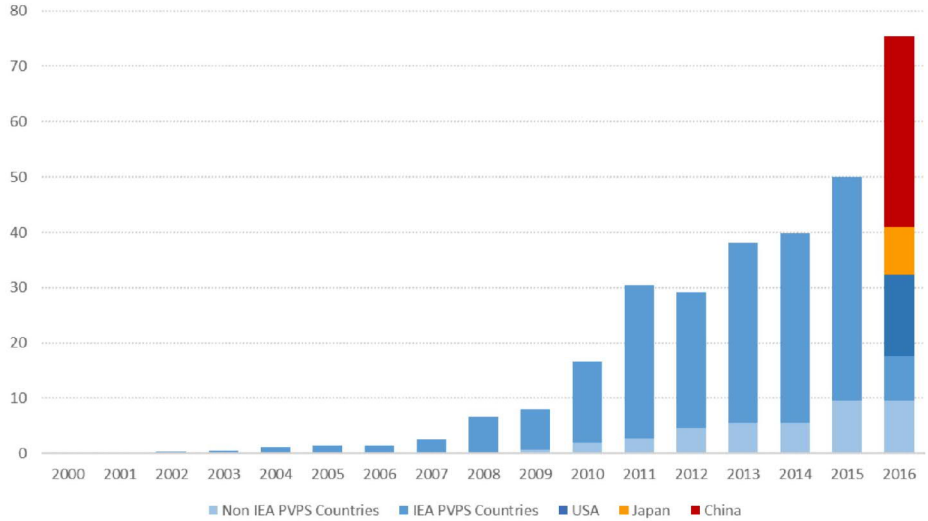
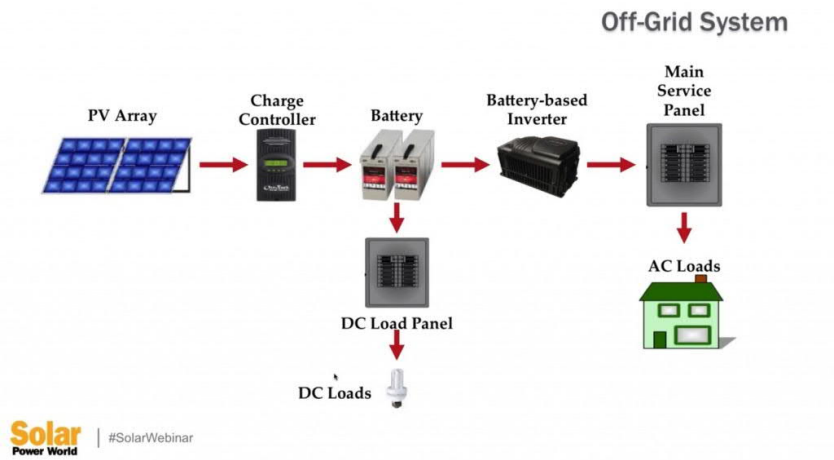
FIGURE 1: EVOLUTION OF ANNUAL PV INSTALLATIONS (GW - DC)

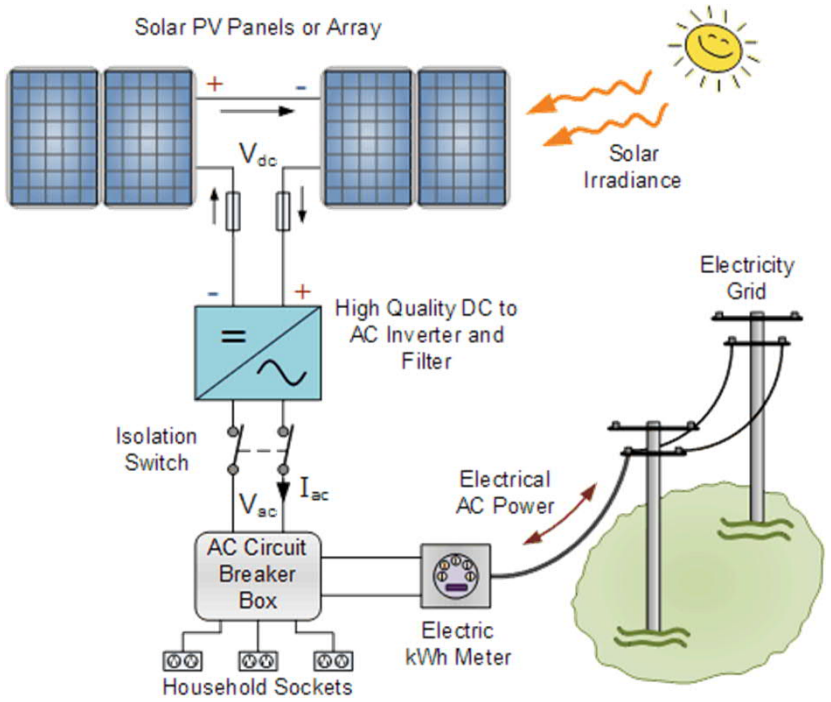


PV power plant concepts

1. PV panel supplying DC loads and/or battery

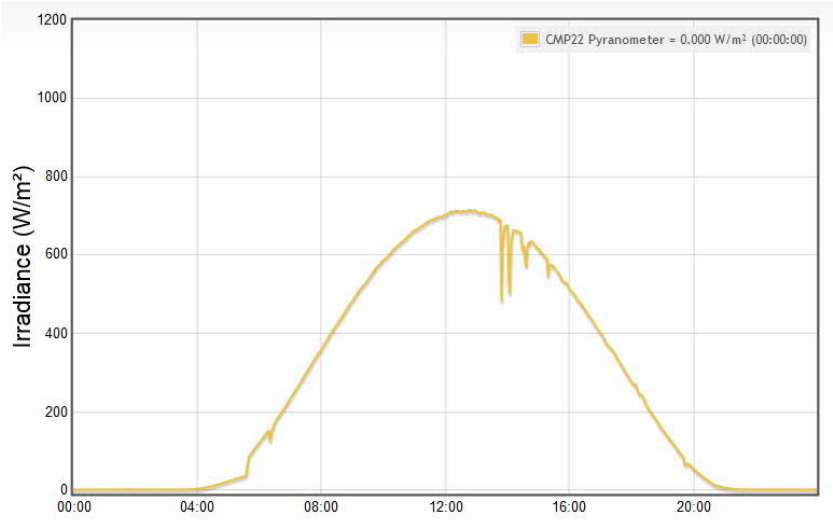


2. Grid-connected PV power plant concepts

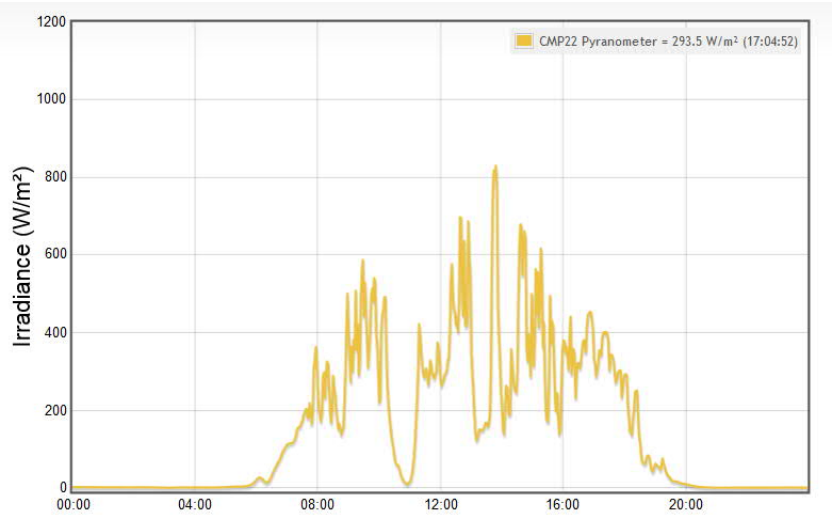


Battery storages

- Energy output from renewables is not constant (clouds, shading by buildings etc)
- The amount of available energy may be hard to predict
- Excess energy can be stored in batteries using power electronic converters
- Constant power output of a renewable energy source can be achieved



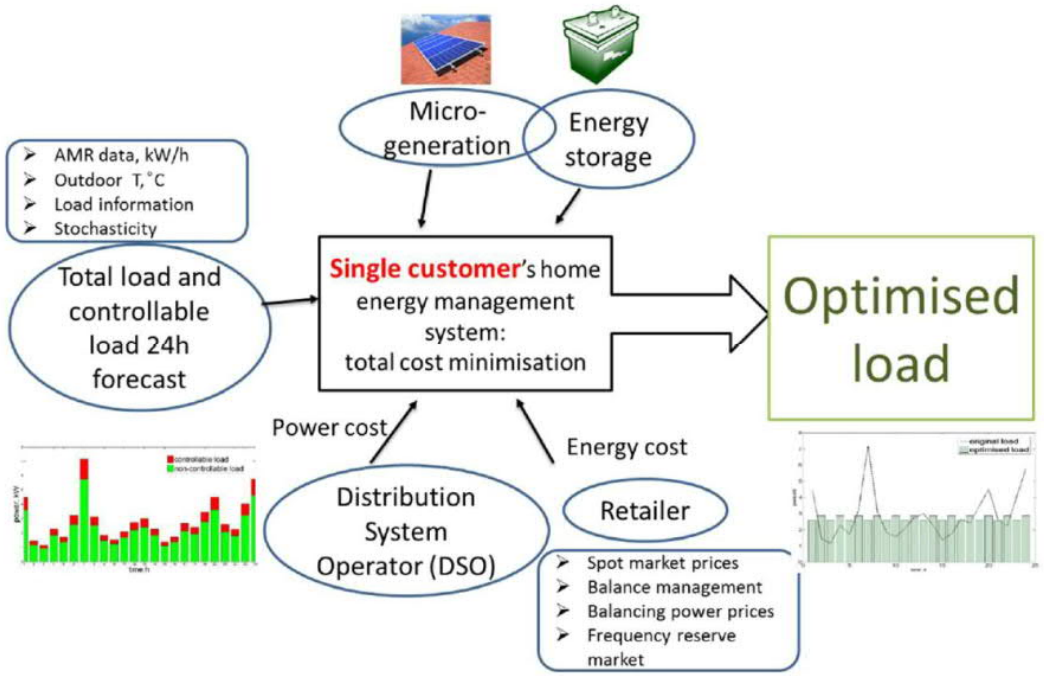
Irradiance at TUT in 5.8.2014.

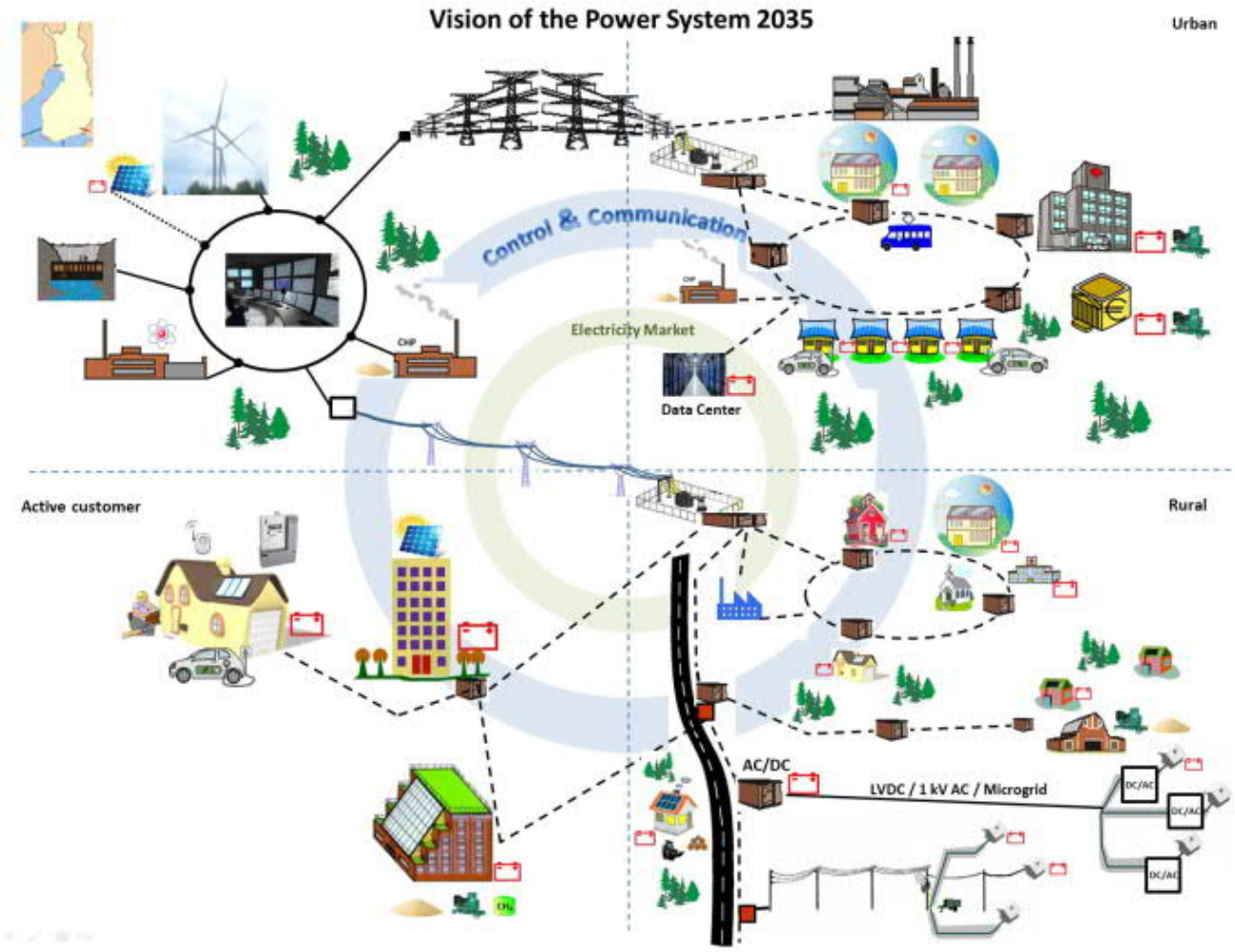


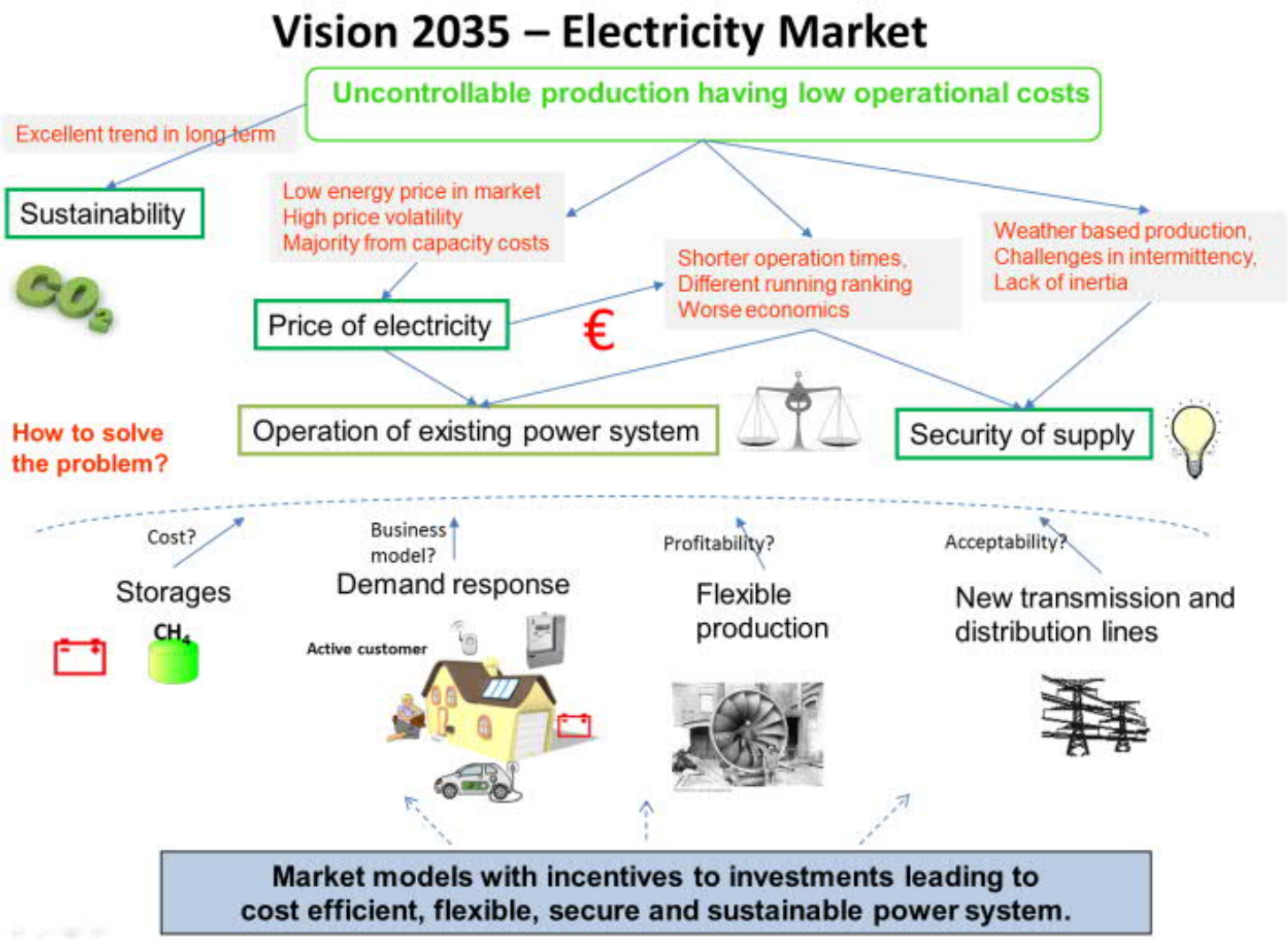
Irradiance at TUT in 3.9.2014.

Change in load profile

- Change in load profile: electric vehicles, heat pumps and renewable power production
- Possibility to predict the load profile
- Possibility to control the load profile (demand response)
- Who controls the system? Customer, electricity supplier or someone else?




Vision of the Power System 2035
Urban
Control & Communication
Electricity Market
Data Center
CHP
Active customer
Rural
AC/DC
LVDC / 1 kV AC / Microgrid
DC/AC
DC/AC
DC/AC


Vision 2035 – Electricity Market
Uncontrollable production having low operational costs
Excellent trend in long-term
Sustainability
Low energy price in market
High price volatility
Majority from capacity costs
Price of electricity
€
Shorter operation times,
Different running ranking
Worse economics
Weather based production,
Challenges in intermittency,
Lack of inertia
How to solve the problem?
Operation of existing power system
Security of supply
Cost?
Storages
CH4
Business model?
Demand response
Active customer
Profitability?
Flexible production
Acceptability?
New transmission and distribution lines
Market models with incentives to investments leading to cost efficient, flexible, secure and sustainable power system.

Vision -> roadmap

- Vision about the future grid
- ✓ Analyzing present grid
- ✓ Compare to other countries
- ✓ Future changes in operational environment
- ✓ Future changes in technology
- ✓ Future changes in business models and services
- ✓ Evaluating alternatives

- Roadmap toward the future grid
- ✓ Defining the research and development projects
- ✓ Co-ordination of the projects
- ✓ Networking

Discuss in groups about the future power system in Laos

1. **Group: mechanical and electrical engineering**
2. **Group: environmental engineering**
3. **Group: policy, regulation, management**