# DG system integration in distribution networks

## The transition from passive to active grids

# Agenda

- IEA ENARD Annex II
- Trends and drivers
- Targets for future electricity networks
- The current status of distribution grids
- Challenges
- IEA ENARD Annex II recommendations

# IEA ENARD Annex II

# IEA ENARD Annex II Objectives

The scope of Annex II is to address DG system integration into low and medium voltage networks including technical, economical, organizational and regulatory aspects. Annex II aims to:

- Build up and exchange knowledge on DG system integration and existing approaches to active network management
- Promote possibilities for the implementation of active distribution networks
- Develop an authoritative set of guidelines to facilitate the transition from today's passive distribution networks to the active distribution grid that will be increasingly required in the future

# IEA ENARD Annex II work programme

Transition from passive to active distribution grid

| | Task 1 | Task 2 | Task 3 |
|---|---|---|---|
| Scope | •Detailed in-country surveys of current state-of-the-art active distribution networks | •Investigation of control & operational strategies to facilitate stable and optimal operation of active distribution networks in either parallel or islanding operation | •To develop a clear vision of active distribution networks |
| Objectives | •Identification of the methodology barriers of the existing network planning tools for planning active networks | •Current state of the art, trends, barriers & recommendations for control & operation of active distribution networks | •Perform dissemination of relevant information about active distribution networks |

# ENARD member countries

The IEA Implementing Agreement ENARD organisation has 14 member countries (status October 2010)

ENARD member country

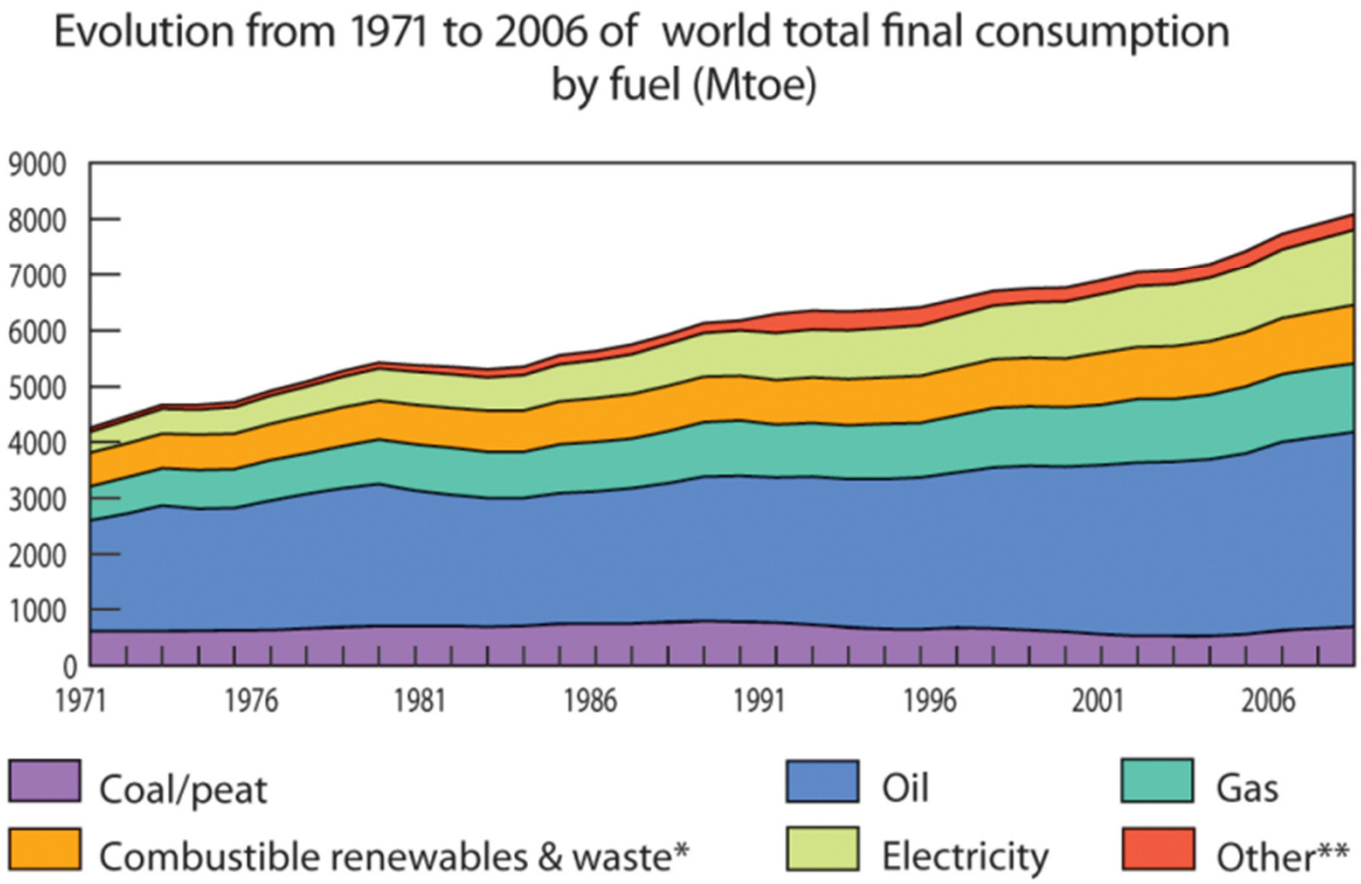
Additional ENARD members:

- United States of America
- Republic of South Africa

# Trends and drivers

# Climate change and electricity networks

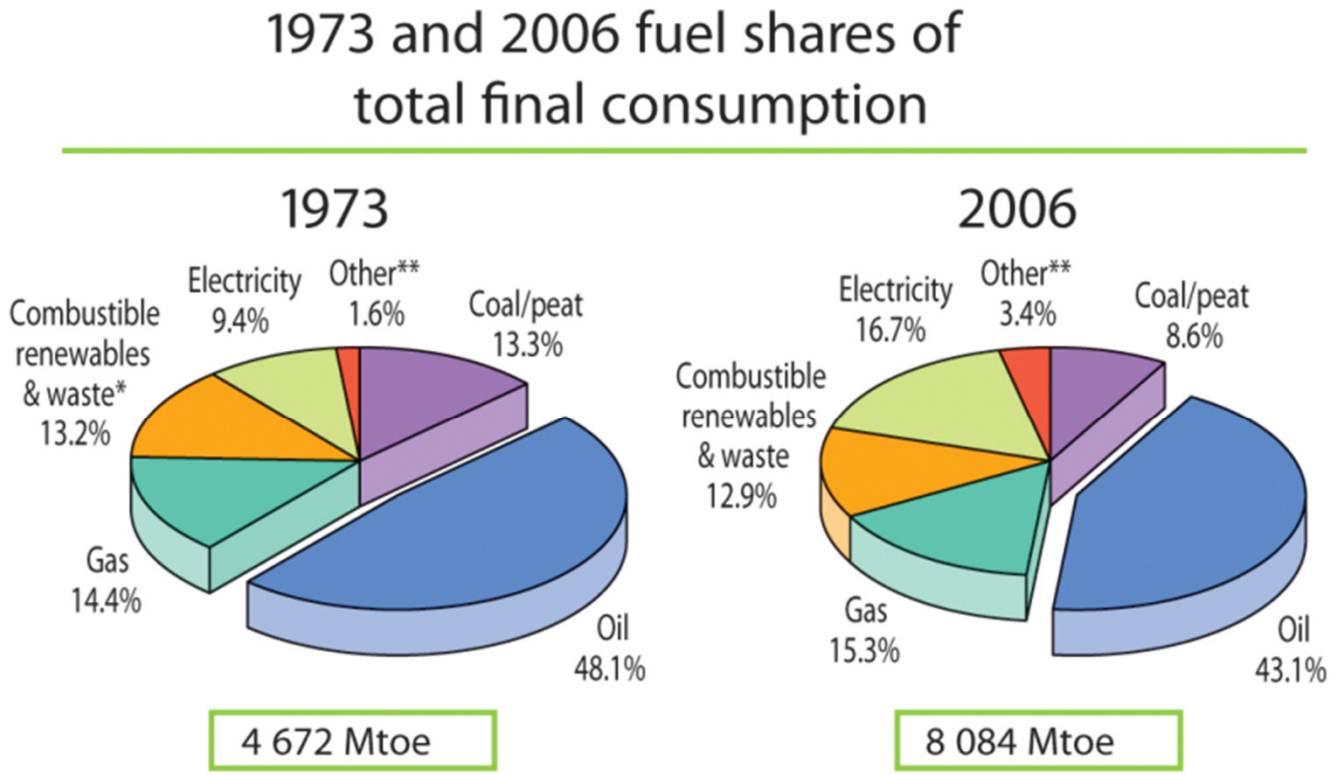
Increasing role of ...




*Source: IEA Key Statistics*

# Climate change and electricity networks

... electricity as energy resource




*Source: IEA Key Statistics*

# Climate change and electricity networks

Electricity networks are a major enabler to reach the goals toward $CO_2$ reduction and mass introduction of renewable energy resources

| | |
|---|---|
| Biggest challenge | Reduce climate change |
| Pollution | by reducing significantly the emission of greenhouse gases |
| Greenhouse gas in the electricity world | with the help of new renewable generation & electric vehicles |

# Targets for future electricity networks

# Targets for future electricity networks

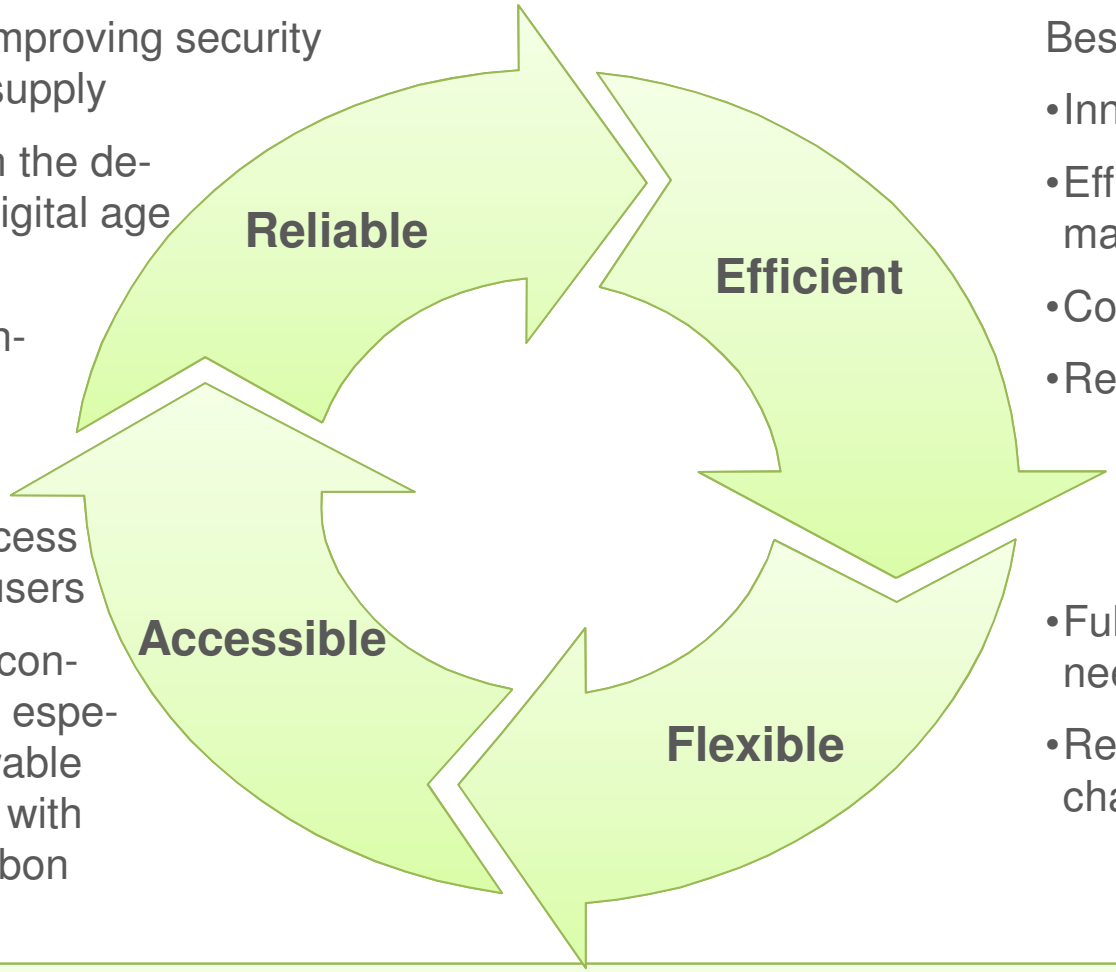
The biggest challenges are to find an optimized grid utilisation and achieving the consumer participation

| | |
|---|---|
| Energy system | • Incentives for the optimization of the entire energy system |
| Efficient energy use | • Network as a platform for efficient energy use and better utilisation of available energy and new services and markets |
| Distributed energy resources | • Integration of a high share of distributed energy resources (mainly based on renewable) into the existing power system |
| Demand response | • Participation of consumers in demand response via advanced smart metering infrastructure |
| New devices and solutions | • Smart Meters, e-vehicles, heat pumps, power electronics, home automation, networks automation |
| Optimized grid utilisation | • Cost efficient DER network integration and optimized utilization of network assets |

# The future network vision

A future network is an electricity supply network that effectively and efficiently meets the world's future needs

- Assuring and improving security and quality of supply
- Consistent with the demands of the digital age
- Resilience to hazards and uncertainties




Best values through

- Innovation
- Efficient energy management
- Competition
- Regulation

- Fulfilling customer's needs
- Responding to the challenges ahead

- Connection access to all network users
- Granting easy connection access especially for renewable power sources with zero or low carbon emissions

# Active distribution network

Annex II definition:

Active networks use **monitoring, regulation and control mechanisms** to actively influence network parameters during operation of the network with **contribution of generators, loads and storage devices**.

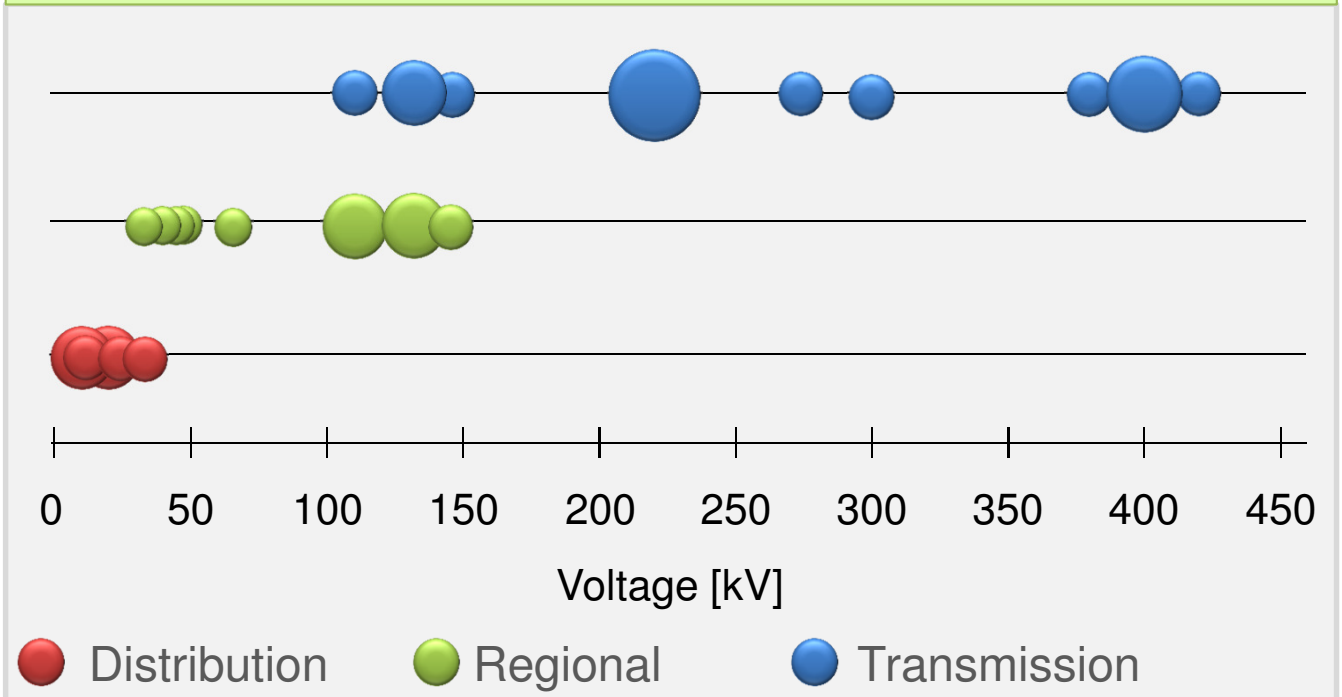
In an active grid, the loads, generators and storage devices can be controlled in real time by means of information and communication technology (ICT).

# Current status of distribution networks

# Current status of distribution networks (1/2)

Generally, power systems are traditionally divided into electricity transmission and distribution network based systems

## Variety of voltages in participating countries




## Remarks

- Some kind of regional network can be seen between transmission and distribution levels. Often, one talks about “regional networks”, “sub-transmission” or similar

# Current status of distribution networks (2/2)

Generally, the degree of automation in the distribution grid is not very high

| | |
|---|---|
| Structure of the distribution grid | • Varies depending on country and also on local circumstances<br>• Used as open ring: the ring connection switch is normally open but can be quickly closed after a disturbance |
| Earthing practices | • Different systems are in use:<br>  • Isolated neutral<br>  • Direct grounded<br>  • Compensated ground |
| Automation in the distribution grid | • The level of automation and remote control in the distribution grid is not sufficient |
| Trend | • An increasing amount of cabling |

# Limitations of nowadays distribution grid for future challenges

The future mass integration of distributed generation and electric vehicles into the distribution grid requires solutions for

1. Control of voltage and frequency by distributed generation
2. Bidirectional power flow management and possible bottlenecks in the distribution grid
3. Using the battery of plug in hybrids and electric vehicles in a smart way
4. Efficient use of the smart meter (additional applications, e.g. demand response)
5. Protection schemes

# Active Networks (1/2)

Commercial planning & design tools for active distrib. networks

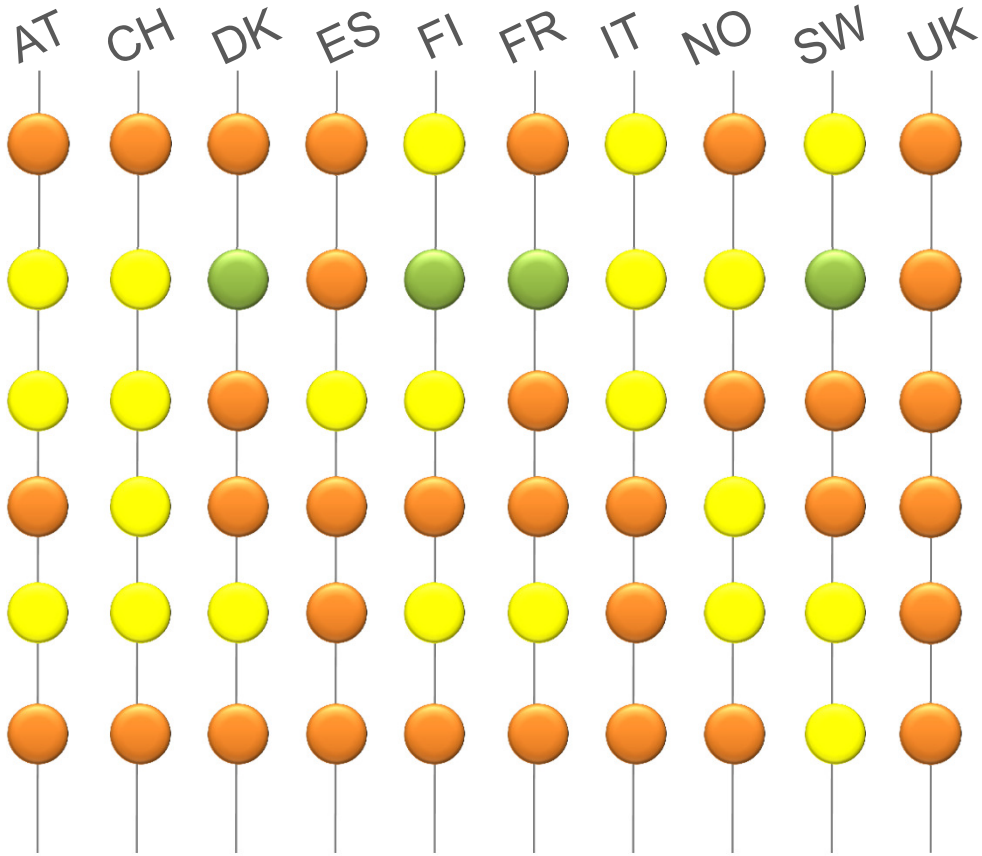
Distribution automation

MV & LV load control

Distribution storage

Distribution islanding

Dynamic circuit rating on distribution level



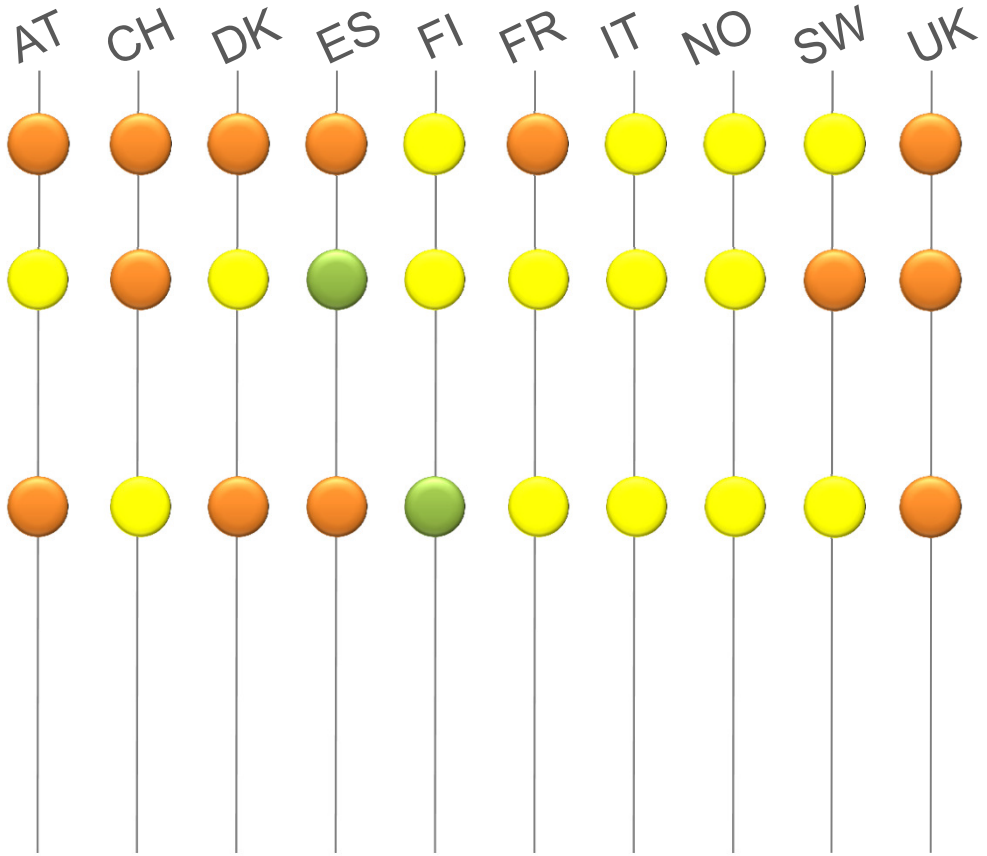

used partially available not available but planned not planned

# Active Networks (2/2)

Distributed generation constraint schemes

DG participating in voltage control (active & reactive power control)

Information & communication technologies in distribution networks

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# Customers

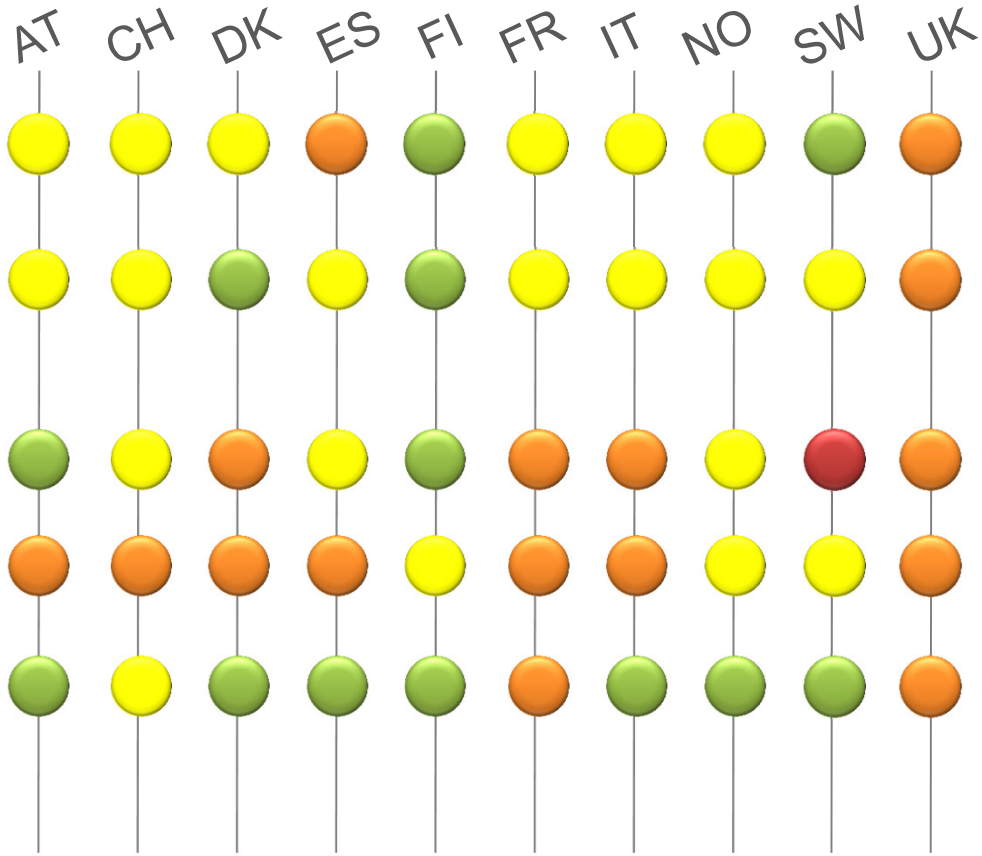
AMR with bidirectional communication

Hourly or more often remote meter reading

Remote disconnect

Demand side management

Supplier freedom




Used  partially available  not available but planned  not planned

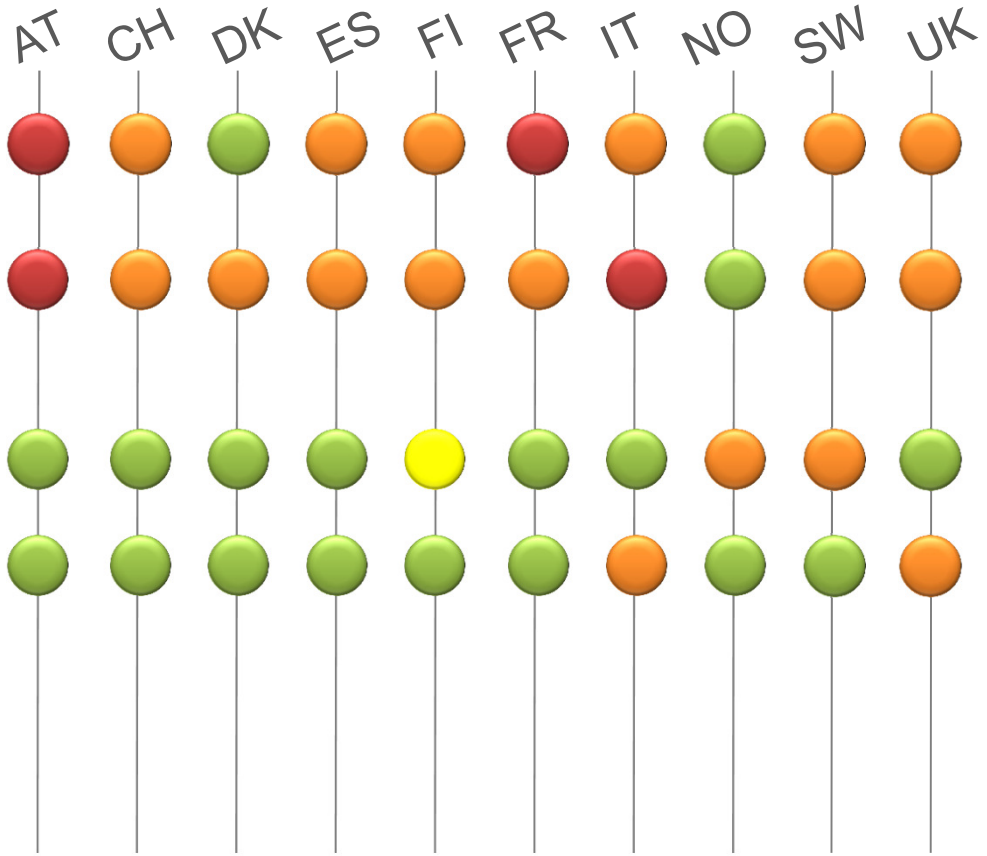
# Economy

Ancillary services from commercial entities

Dynamic energy price at distribution grid level

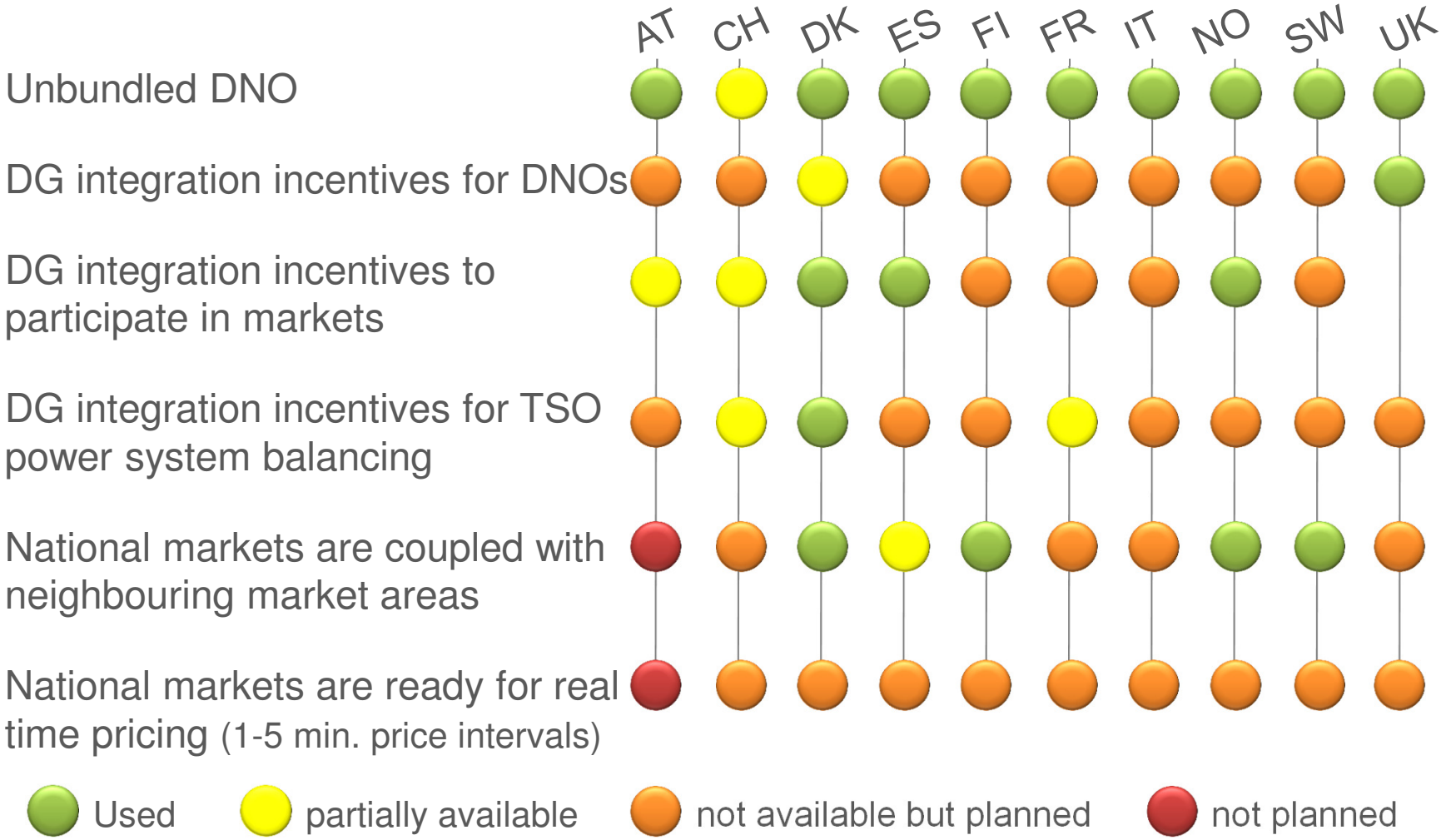
Fixed tariffs for DER

Market tariffs for DER




Used  partially available  not available but planned  not planned

# Regulatory


AT
CH
DK
ES
FI
FR
IT
NO
SW
UK
Unbundled DNO
DG integration incentives for DNOs
DG integration incentives to participate in markets
DG integration incentives for TSO power system balancing
National markets are coupled with neighbouring market areas
National markets are ready for real time pricing (1-5 min. price intervals)
Used
partially available
not available but planned
not planned

# Conclusion from the country overview

Due to the different starting points, each country needs its individual smart grid

| | |
|---|---|
| Different starting conditions | • The country overview shows that in regulatory, economical and technical questions exists quite different starting points in the ENARD member countries |
| Harmonisation? | • A harmonisation of the regulatory, economical and technical aspects in the European countries in order to have a common starting point for a smart grid is impossible |
| Tailor-made smart grid | • Each country needs its tailor-made active network solution |
| Actual situation | • Different starting points → different challenges → requires different solutions<br>• Currently no ENARD Annex II member country has widely implemented measures for active distribution network operation! |

# Challenges

# Challenges for future networks

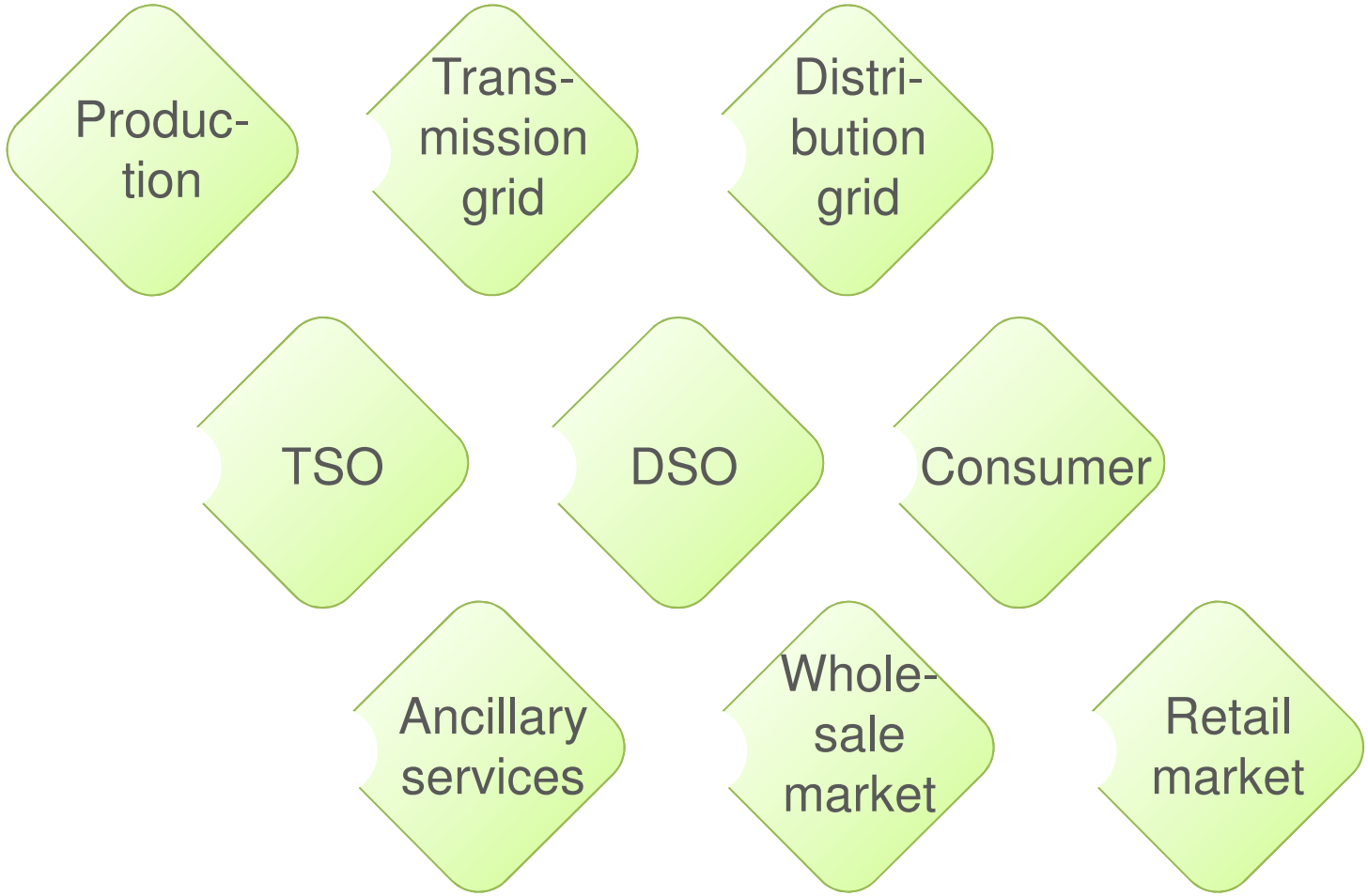
| | |
|---|---|
| Transition | • The development of technical solutions for the transition from passive to active distribution system must be found |
| More complex system operation | • More complex requirements for maintenance and system operation need to be fulfilled |
| Communication interfaces | • Integrated and standardized communication interfaces need to be implemented and financed |
| Higher capa-cities in trans-mission networks | • Higher transmission capacities for networks are required |

# Challenges for future networks

| | |
|---|---|
| Demand side management | • In many countries the willingness to participate in demand side management and demand response as well as the question who is going to pay for the expenses for the additional infrastructure is not clearly answered yet |
| Standards and market rules | • Standards and market rules for the interaction and integration of generations units, consumers, storage devices and network assets must be adapted and introduced |
| Legal & regulatory framework | • Adapted legal and regulatory framework need to be developed |
| New contract models | • There is a need for new contract models between network operators, grid users, power providers and associated business models |

# ADN challenges

The introduction of a ADN will result in changes along different players, technologies and functionalities



# ADN challenges: Production

The ADN allows a mass rollout of distributed generation units

## Actual situation

- Production is nowa-days focussed on big power stations which feed into the grid usually at high voltage level

## ADN

- Significant higher share of distributed generation which feed into the low voltage
- Active integration of DG in network operation

## Challen-ges

- Economic coexi-stence of very large and very small power stations
- Degree of self-supply of a country – per second or per year?

# ADN challenges: Ancillary services

The ADN will also see new devices in the grid as flexible network assets (power electronics), flexible loads, flexible generation and storage

## Actual situation

- Nowadays: Balancing energy, voltage control, black start availability mainly on Transmission level

## ADN

- Balancing and ancillary services within distribution network required due to fluctuating generation

## Challen-ges

- Provide ancillary services also on distribution network level
- Business models for ancillary service on DNO level
- New cooperation relationships between TSO and DNO

# ADN challenges: TSO

The TSO has to operate secure and efficiently a grid with a huge share of new renewable power stations

## Actual situation

- TSO is responsible for balancing
- TSO provides ancillary services
- Mainly unidirectional power flows to the DNO

## ADN

- ADN including fluctuating DG is going to have influence on transmission networks
- The TSO has to manage huge fluctuating renewable generation units (wind farms, photovoltaic)

## Challen-ges

- TSO will see new congestion points
- New stability issues
- New cooperation relationships between TSO and DNO
- Who will provide balancing energy in the future (DSO, storage owners, etc.)

# ADN challenges: Market Design

With the mass introduction of distributed generation the market place focus will also shift more and more to the distribution grid level

## Actual situation

- The wholesale market is nowadays established on the very high voltage levels (220 kV and 380 kV)

## ADN

- A significant higher share of distributed generation will partially shift the market to the distribution grid

## Challen-ges

- New market designs are needed taking local aspects into account
- New market roles are needed
- Liquidity of the different markets
- Flexible market oriented demand response is necessary

# ADN challenges: Distribution grid

A huge wave of technology is needed to update our nowadays distribution grid

## Actual situation

- The distribution grid has nowadays low automation degree in many countries

## ADN

- In order to manage huge shares of fluctuating units, storage units and smart interfaces (to generation and loads) are needed in the future

## Challen-ges

- Mass integration of ICT
- Working out new smart grids planning software
- Integrate new components for control purpose (e.g. FACTS)
- Develop smart interfaces

# ADN challenges: DSO

The transition from passive to active network operation is going to change the daily business of network operators

## Actual situation

- Todays MV and LV networks do not utilize automation and remote control in a large extend
- “Fit and forget” approach for DG integration is widely used

## ADN

- The DSO will get a much more active role in the future: DG coordination, demand side management, managing the battery of electric vehicles, etc.

## Challen-ges

- Who will manage distributed generation devices – owner and/or DSO?
- Balancing markets for small production units are needed
- “Observe and Control” approach is needed

# ADN challenges: Consumer

The consumer is going to have an active role in future electricity networks

## Actual situation

Some active involvement of consumers to network operation

ripple control / day and night tariff / load shedding

## ADN

Active integration of consumers to network operation (e.g. demand response)

Demand follows generation

## Challen-ges

Appropriate pricing and contract models for consumers

Smart meter as interface to the consumer

Home automation is needed

Transition from consumer to prosumer

# Recommendations (1/6)

**Clear energy strategies**

- Clear national and international energy strategies are required

  A clear commitment and vision for future electricity mix
  - Which amount of a certain technology
  - Should a country be self-sufficient (per year or per second)

**Clear structure & continuity in regulation**

- Many different models are used, thus a clear structure and continuity of regulation models is required, that is fair for DNO and DER – changing regulatory framework is a critical uncertainty for long term investments in electricity networks

**Harmonization of support schemes**

- Fixed feed in tariffs are a clear incentive for DG but in many cases act as barrier for active network integration. The different DG support measures and level of support (regional, national and international) need to be harmonized

# Recommendations (2/6)

**Cost handling**

- Clear handling of R&D demonstration costs by DNOs and related legal security and exceptions for demonstration/trial projects is required (e.g. Benchmarking of DNOs without considering R&D efforts)

**Market follows power systems dynamics**

- Market must follow the dynamics in the power system as much as possible and must allow the DER integration into the distribution Grids
- Aggregator in the market needs to be clearly defined
  - Markets and business models in the distribution grid level will be needed (e.g. ancillary services)

**New contract and business models**

- New contract and business models, due to different technical and economical interests of DNO and DER (quality and security of supply versus maximizing power feed in) need to be introduced for new and existing DER units..

# Recommendations (3/6)

**Efficient use of electricity networks**

- Efficient use of electricity networks will be essential in the future. Networks will be operated more efficiently if DNOs are able to take more system operation responsibilities for active network and active use of DG resources and demand response

**Smart meter**

- The smart meter is a possible enabler for DG system integration. A flexible smart meter with bidirectional communication can be sensor and actor in future networks. Open questions
  - Cost for smart meters and who is going to pay
  - Business models for metering (liberalized metering)
  - Network operators, DG operators & consumers should benefit

**Harmonized tech. re-quirements & standards**

- Harmonized technical requirements and standards (for DG, communication and smart metering equipment) are needed in order to ensure quality and safety of future active networks

# Recommendations (4/6)

**Harmonized procedures for grid connections**

- Harmonized and more systematic procedures for establishing grid connections need to be established, for instance information flow between DG unit operator and DNO

**Interface between distribution & transmis-sion grids**

- More focus should be laid on the interface between distribution and transmission networks

**Flexible storage and loads**

- The usage of storage and more flexible loads, for instance electric vehicles, must be increased. New applications such as electric vehicles should not be seen only as a new load type but also as a possibility for active operation

# Recommendations (5/6)

**Reactive power management**

- Reactive power management will be more and more important and should be implemented

**Enhanced protection strategies**

- New and enhanced protection strategies and equipment is required for networks with high share of DG

**Build up new knowledge**

- Due to the increasing system complexity, in general for future network operation DNOs as well as education institutions need to build up new knowledge

# Recommendations (6/6)

**New Demonstration projects**

- More active network demonstration projects are necessary to gather more practical knowledge and best practice examples for future network operation
- Ongoing knowledge exchange & intensified dissemination are needed

**Biggest challenge: grid policy & regulatory aspects**

- Grid policy and regulatory aspects were identified as the most challenging issues concerning massive DER integration in distribution systems. Therefore in future activities dealing with DER and network related grid policy issues should be intensified.