Energy Storage Opportunities and Pitfalls in Sub-Saharan Africa: The Value of Standards

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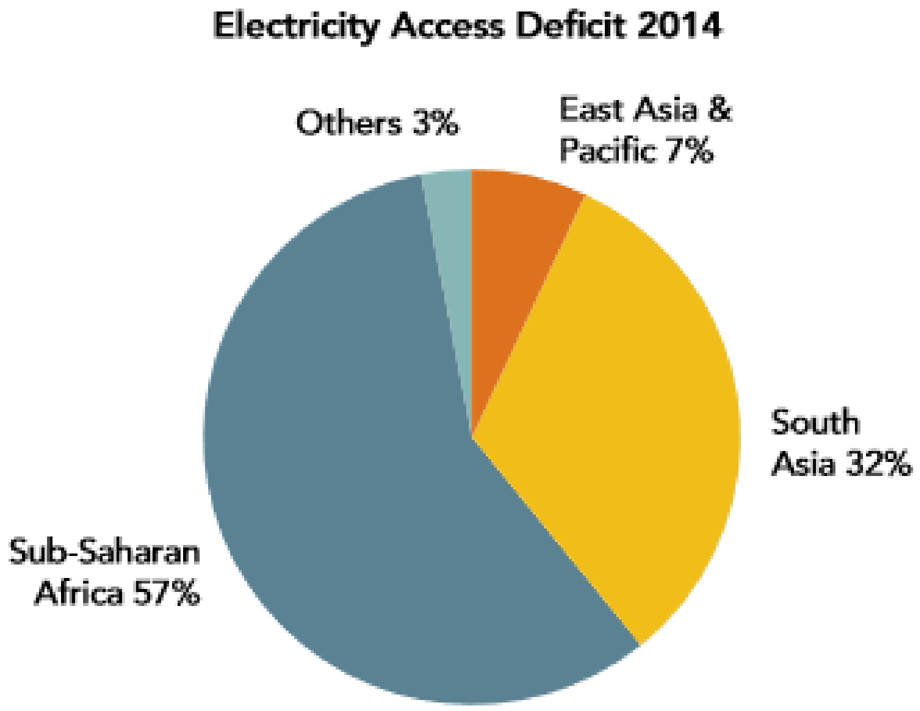
OUTLINE

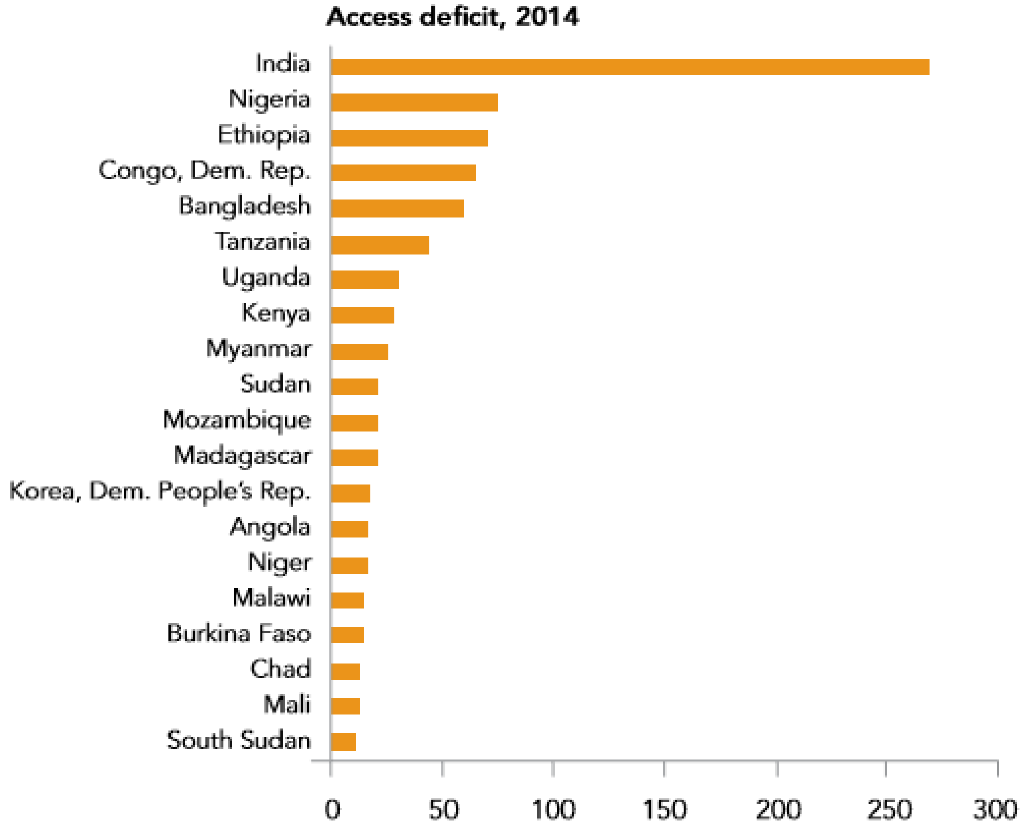
- Overview of Africa and West Africa electric power sector
- Regional grid interconnections and power pooling
- Distributed generation as viable solution for remote power systems
- Integration of renewables as key driver for energy storage
- The need for standards
- Conclusion

OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

- 17 of the top 20 countries with high electricity deficit are in Africa



Source: Data from IEA and World Bank 2017.

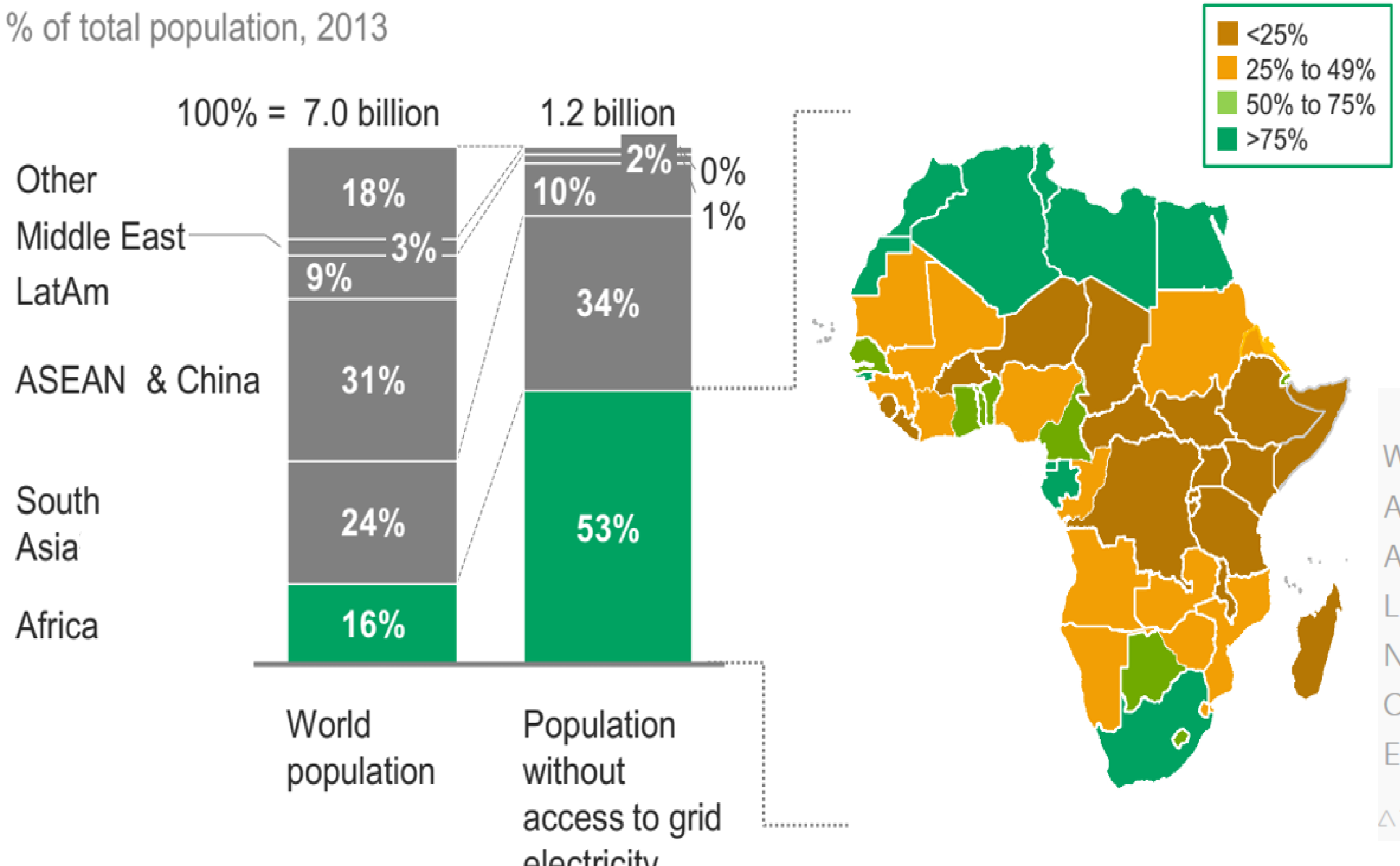


Source: IEA and World Bank 2017
Note: These countries account for more than 81 percent of the global access deficit.

Top 20 countries for access deficit in electricity, 2014

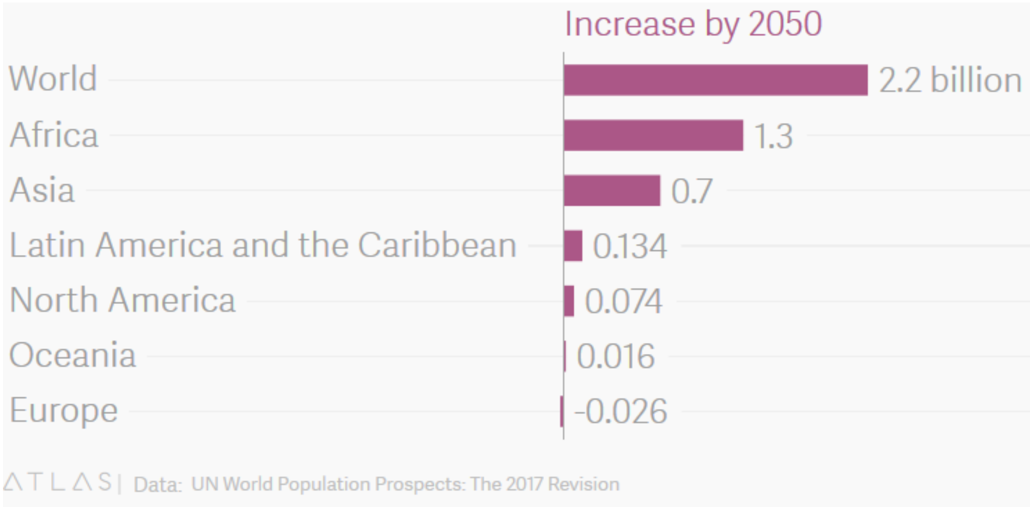
OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

Distribution of population without access to electricity by region



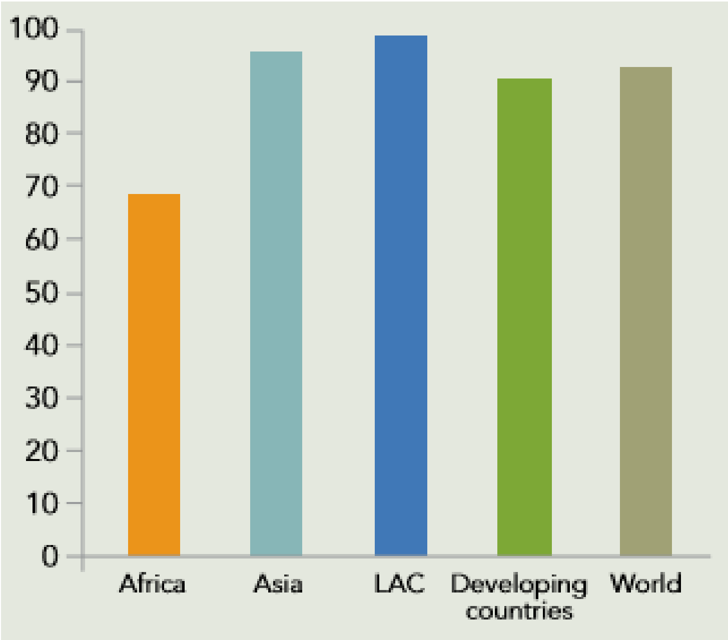
Source: AfDB, 2016

- ❑Africa has the highest population without access to electricity
- ❑Africa has the fastest growing population

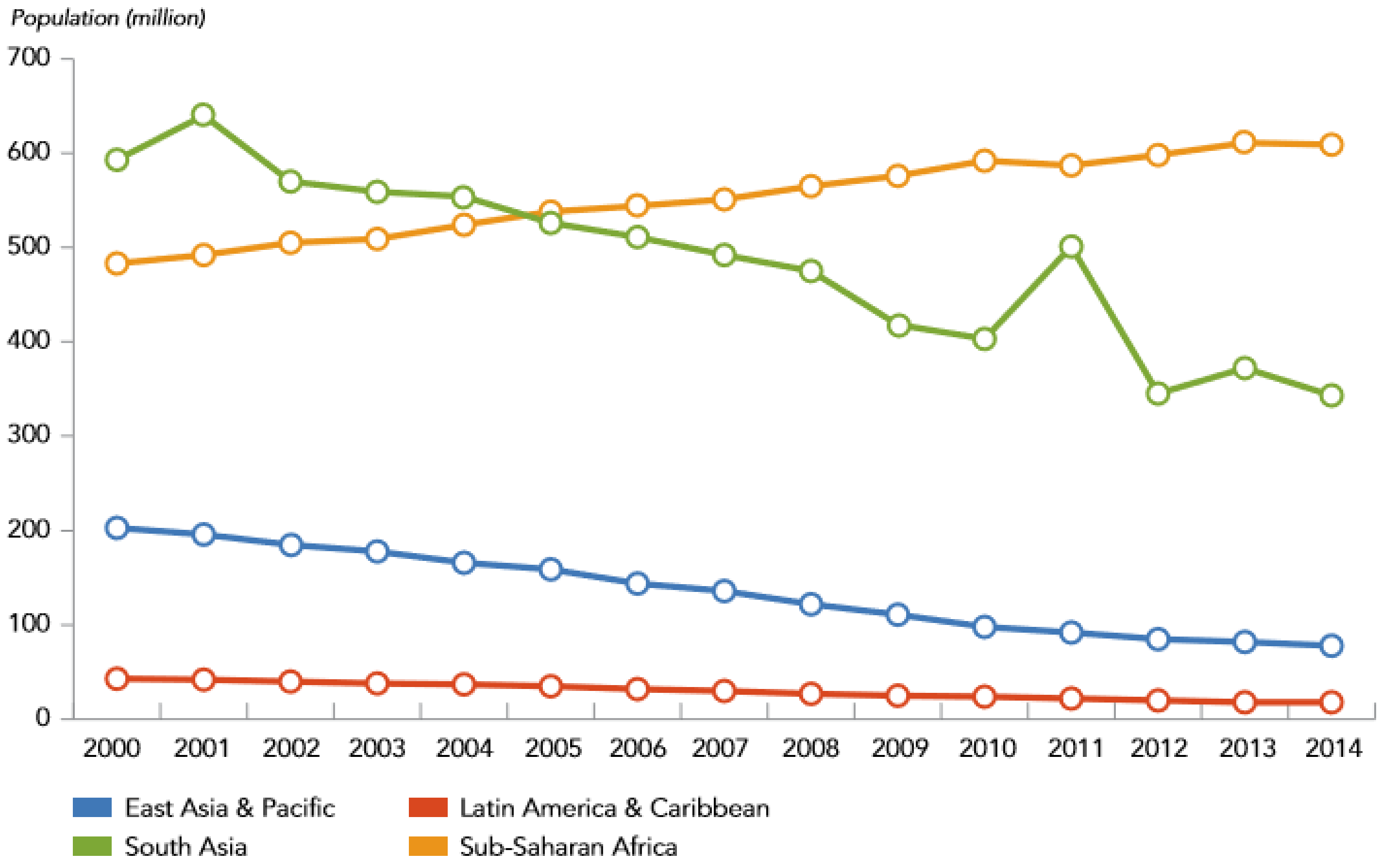


OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

- Sub-Saharan Africa is not keeping up with population growth for electricity access



Percentage of urban population with electricity by world regions

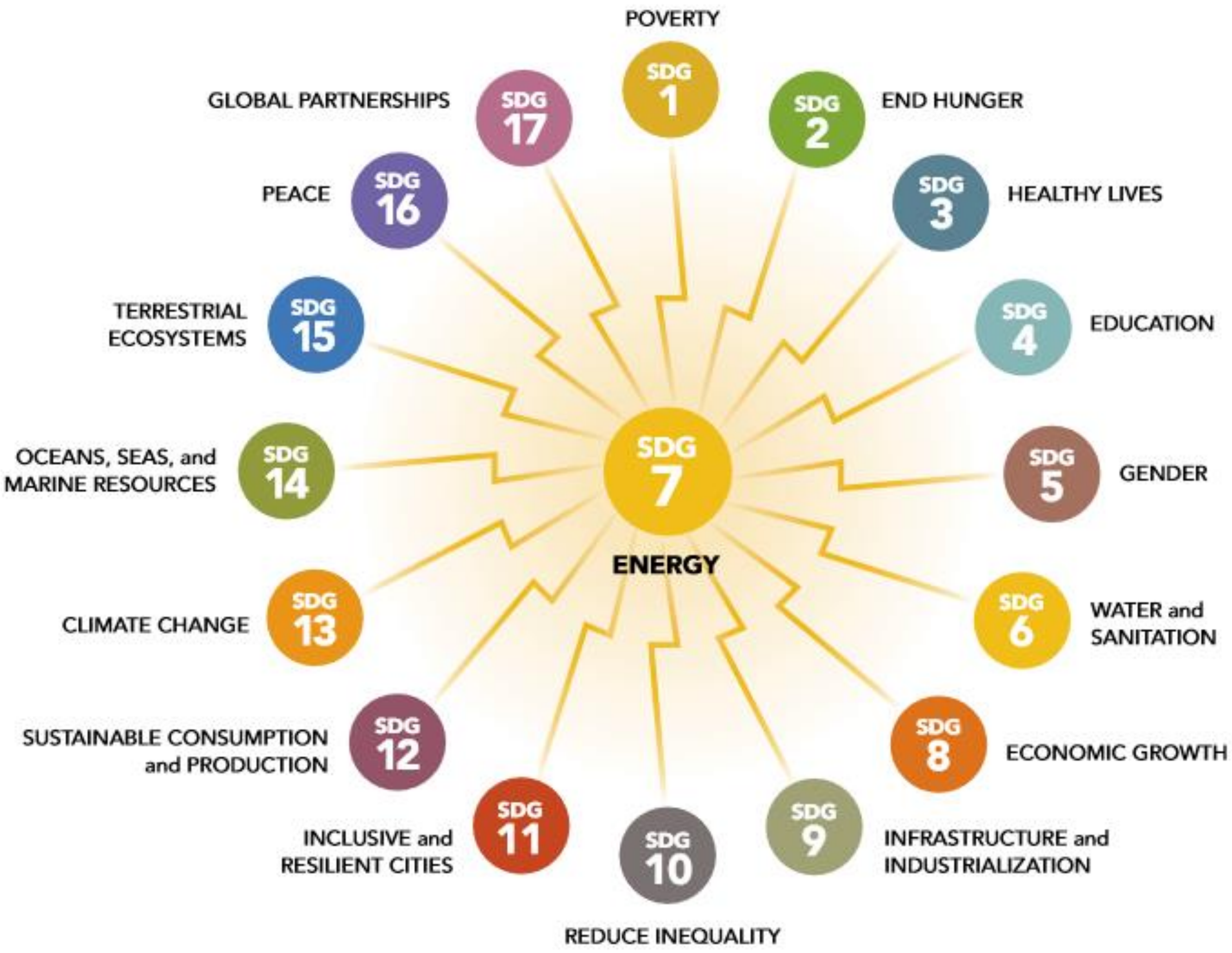


Source: Data from IEA and World Bank 2017

Trends in population lacking access to electricity, 2000–2014

OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

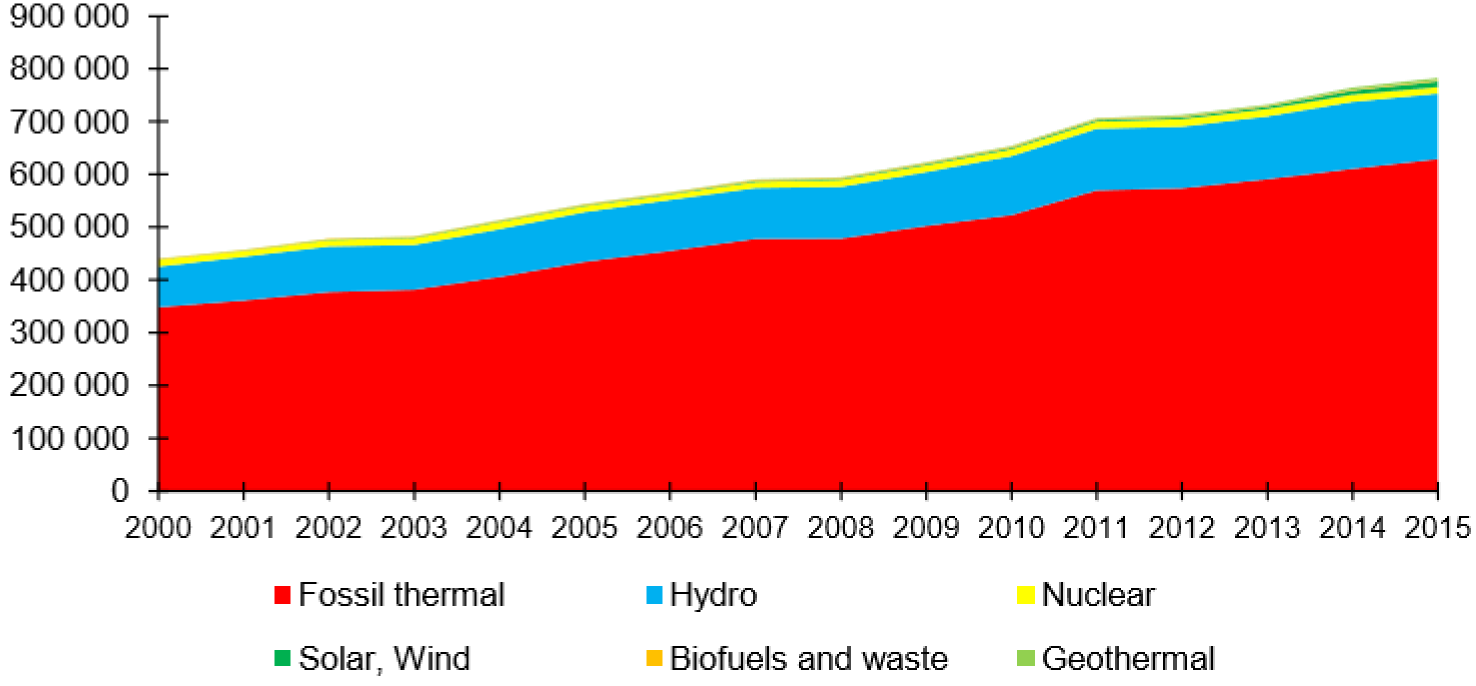
- Energy is linked to all the remaining Sustainable Development Goals
- Sustainable Development Goal on Energy (SDG7): ensure access to affordable, reliable, sustainable and modern energy for all



OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

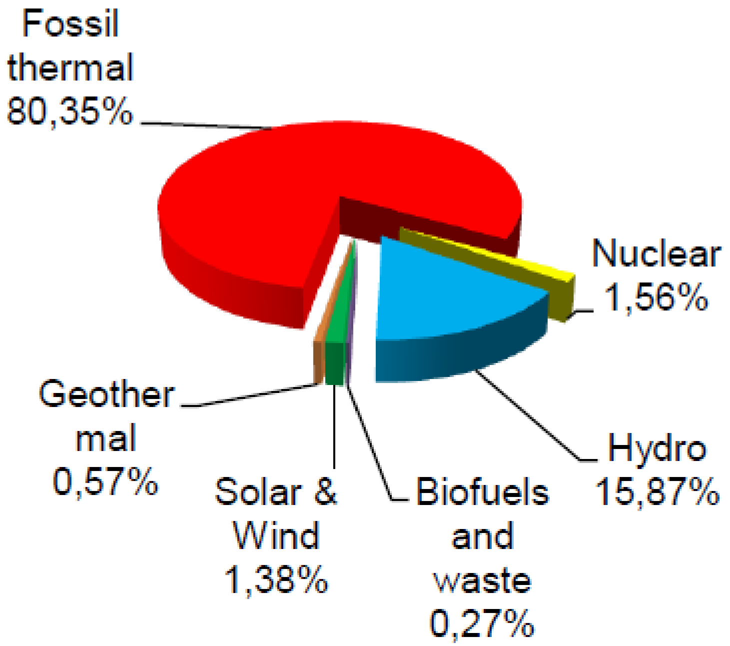
- Africa is fairly endowed with significant energy resources for electricity generation, but they are underdeveloped and unevenly distributed
- Energy storage is a crucial tool for enabling the effective integration of renewable energy and unlocking the benefits of local generation and a clean, resilient energy supply
- There is a limited energy storage market activity in Sub-Saharan Africa to date

OVERVIEW OF AFRICA ELECTRIC POWER SECTOR



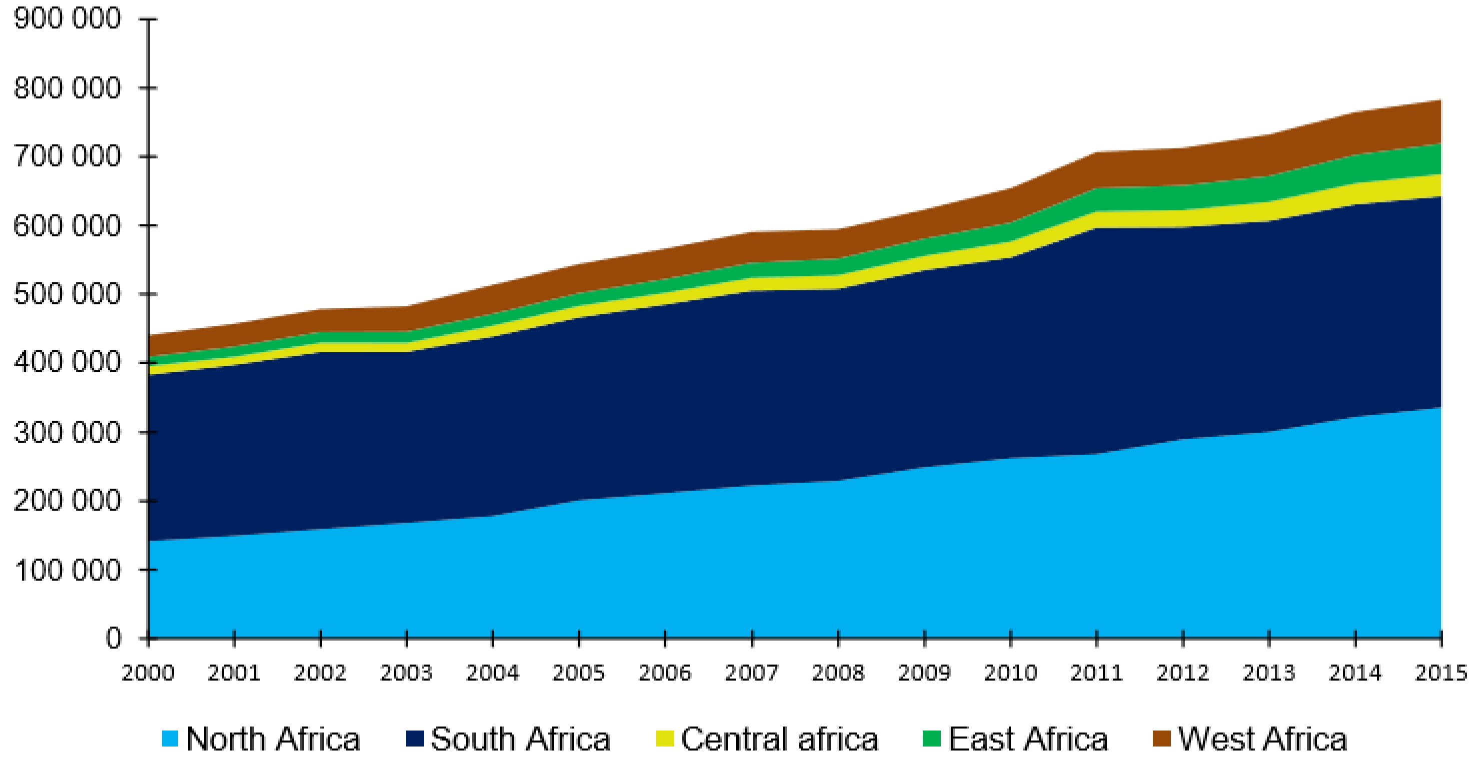
Electricity Generation by Fuel – Africa (GWh)

2 015



782 977 GWh

OVERVIEW OF AFRICA ELECTRIC POWER SECTOR



Electricity Generation by region – Africa (GWh)

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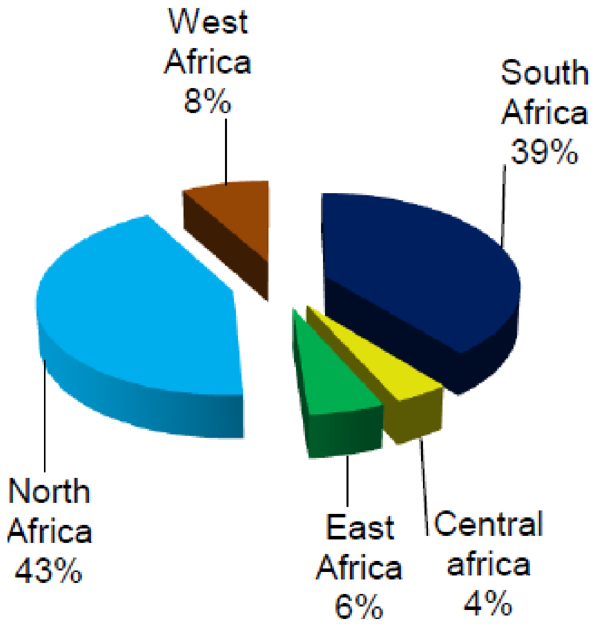
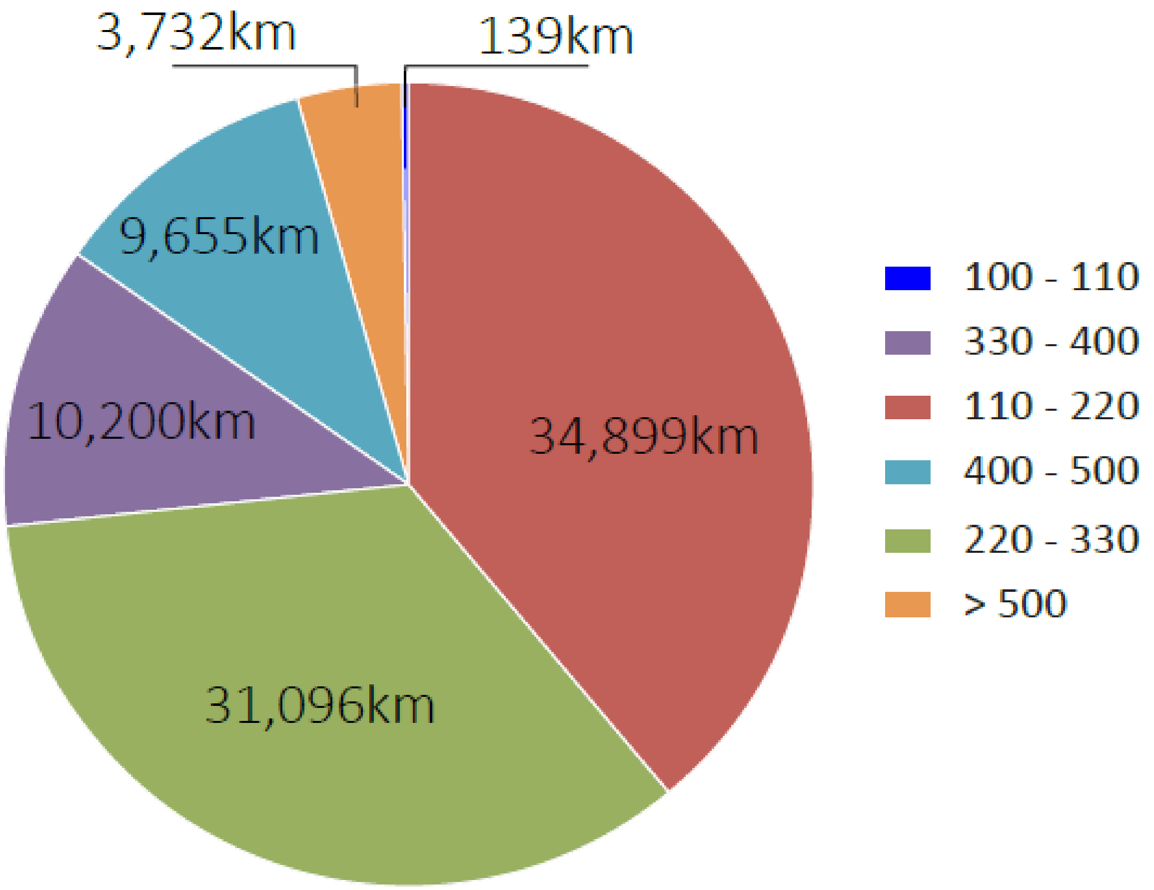


782 977 GWh

OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

- Africa's existing power transmission system (defined as lines with a voltage equal or above 100 kV), has a total length of 89,731 km
- It is small compared to the area of the continent, corresponding to a density of 3.29 m of transmission line per km^2.
- Absence of a unified or standardized specifications: **Africa has at least 15 levels of transmission line voltages from 100 kV to 700 kV** (AfDB, 2014)



Source: (AFREC, 2015)

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AFRICAN REGIONAL POWER POOLS

AFRICAN REGIONAL POWER POOLS

- Challenges of interconnected grid systems
  - Load and frequency control
  - Technical compatibility and operational coordination
  - Difficulties of joint planning and operation
  - Capacity building and compliance
  - Regulation enforcement

- Why Power Pool?
  - "Power pools are the best strategy to deal with Africa's energy problems" - UN Economic Commission for Africa, 2005

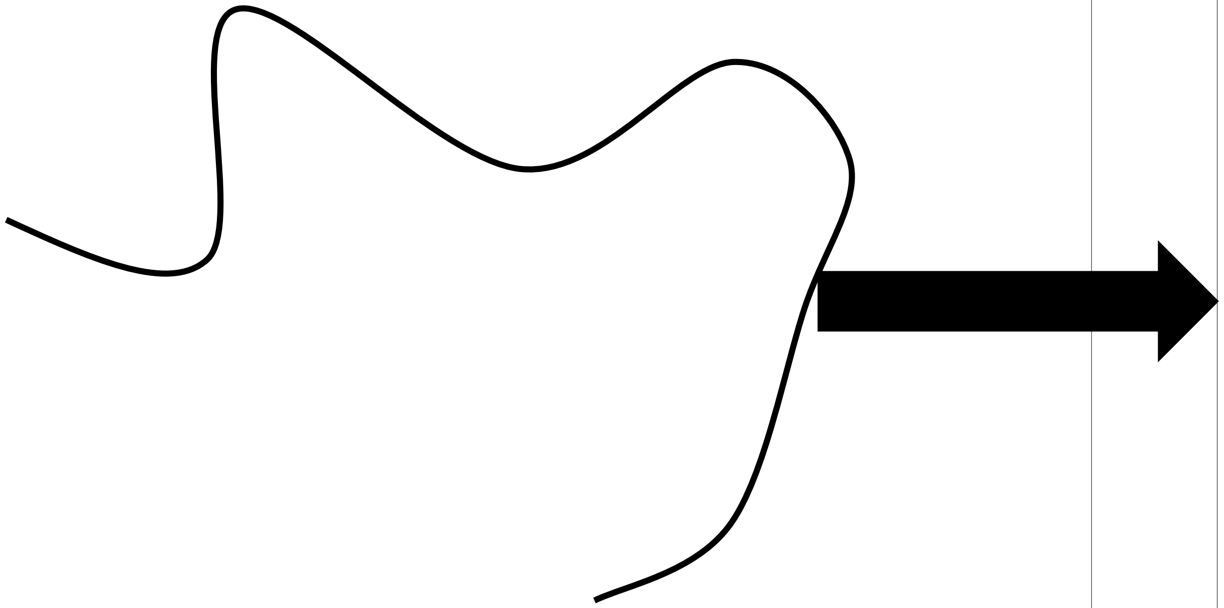
AFRICAN REGIONAL POWER POOLS

Benefits of Interconnected Grid Systems

- ❑Exchange of peak loads & Increase diversity factor
- ❑Economic efficiency
  - Better utilization of the most efficient generators
  - Capture economies of scale for new projects
- ❑Security and reliability of supply
  - Increase diversity of primary energy sources
  - Larger systems are more robust against contingencies
- ❑Reduced plant reserve capacity
- ❑Resource sharing
- ❑Reduced investment in generating capacity

THE WEST AFRCAN POWER POOL

The West African Power Pool is divided into Zone A and Zone B



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THE WEST AFRCAN POWER POOL

The Challenge

- ❑ Regions must have:
  - ❖ Fairly developed grid infrastructure
  - ❖ Adequate generating capacity
  - ❖ Legal framework for cross-border trading
  - ❖ Regional institutions and regulations
- ❑ Change in mindset from a national to a regional/global mentality
- ❑ Transmission Regulation:
  - ❖ Transmission investment
  - ❖ Access to network
  - ❖ Network pricing

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DISTRIBUTED RENEWABLE GENERATION

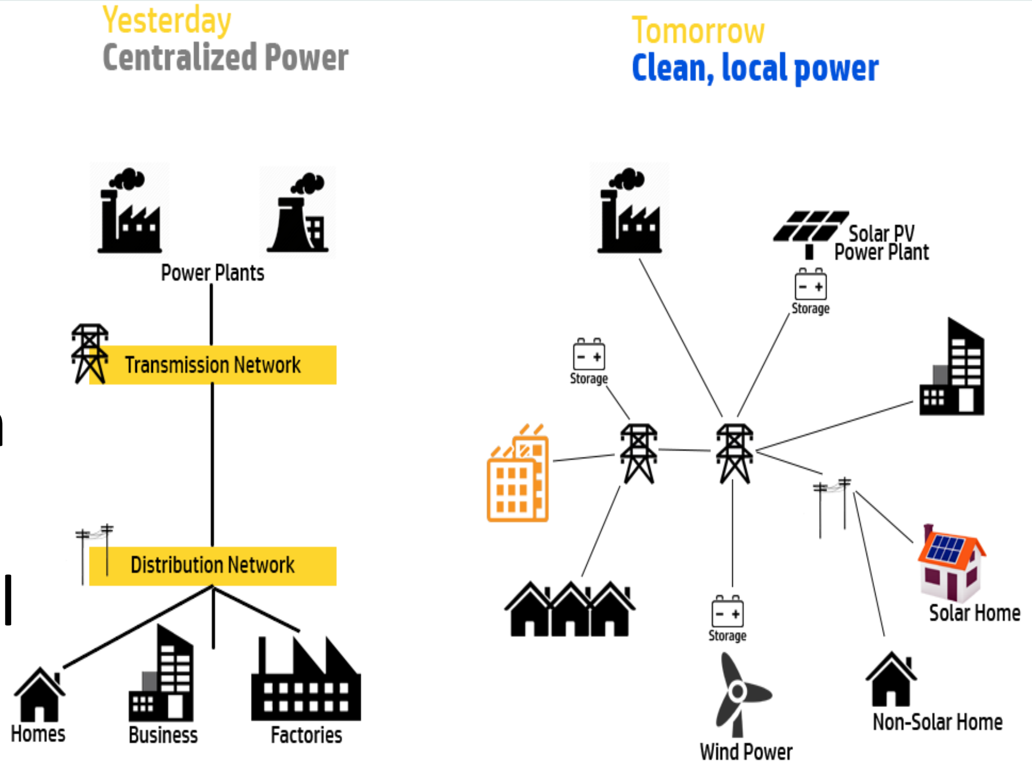
- ❑Urban–rural divide in terms of access to modern energy and other services
- ❑DRG allows for reduced electrical losses from transmission and distribution by locating generation close to the point of use
- ❑DRG is modular and can be tailored to end-user requirements
- ❑DRG is more able to match growing demand by using smaller units, thereby reducing the impact of large stepwise additions to centralized generation capacity.

DISTRIBUTED RENEWABLE GENERATION

- With high penetration of DRG the mini/micro grids becomes dynamic, distributed, networked, and fairly easy to integrate into a central electric system
- The importance of intelligent and enabled technologies such as sensors, IEDs, and network management systems must not be overlooked when planning small or large scale distributed generation
- Good planning, appropriate requirements and clear regulations for mini/micro grids limit the risk of stranded assets and enable better business cases for the involved stakeholders

DISTRIBUTED RENEWABLE GENERATION

- Technical insights include preparing the micro/mini grid for integration into the centralized grid in the planning stage.
  - When the centralized grid expands into the area of the micro/mini grid, it can then directly connect to the micro/mini grid, with the micro/mini grid operating as a cell to the centralized grid.
  - To achieve this objective, the micro/mini grid equipment needs to comply with the technical requirements of the centralized grid



RENEWABLE ENERGY AND ENERGY STORAGE

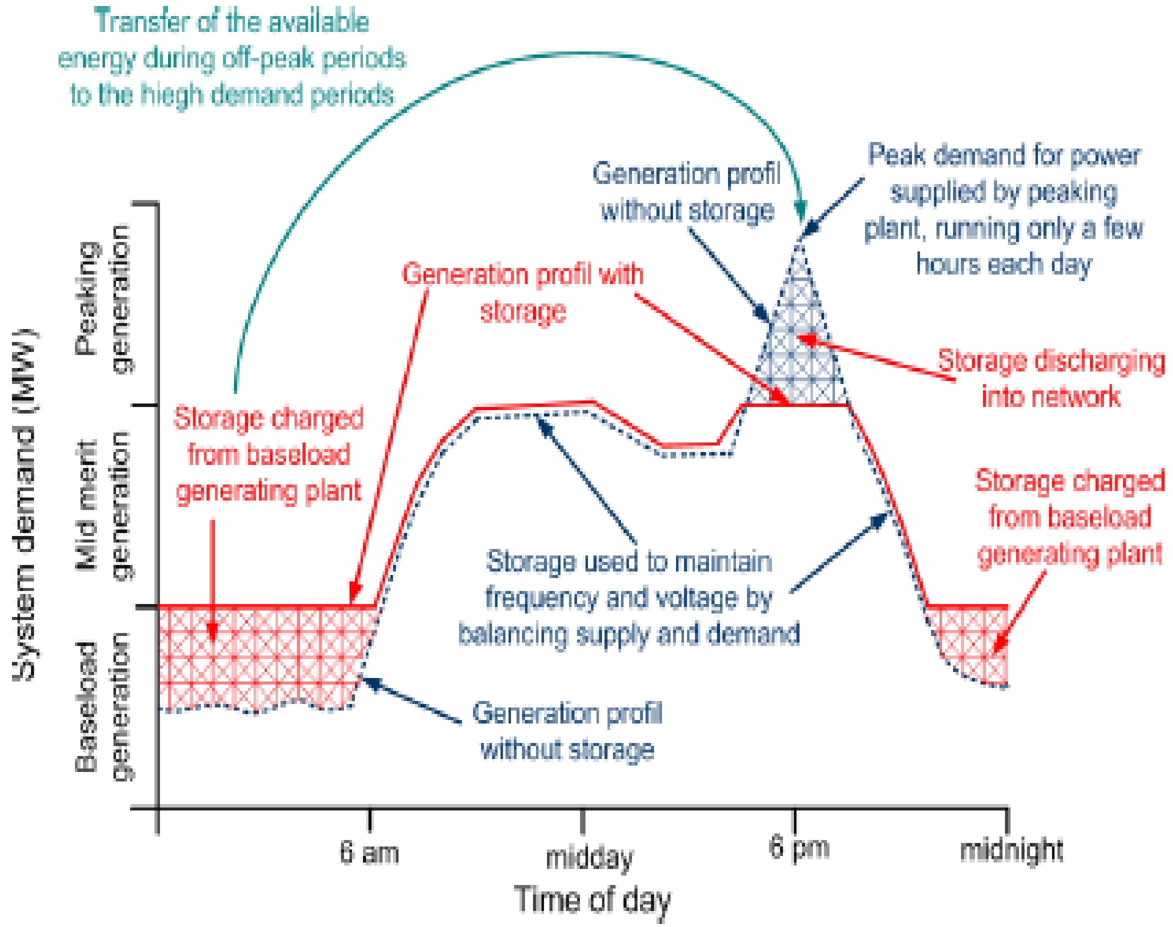
Energy storage devices perform a wide variety of different functions at distributed and central levels:

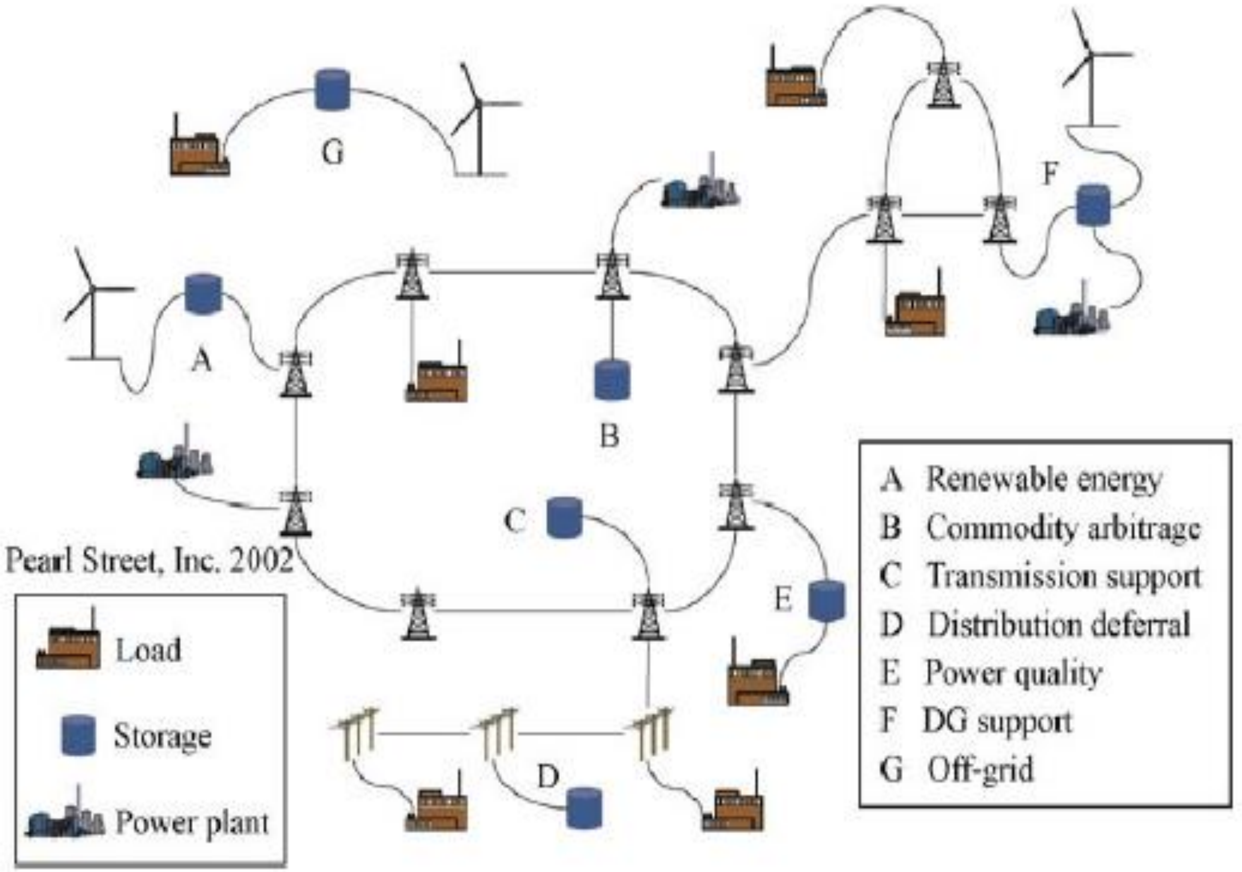
- Permanently integrating renewable energies
- Backup for higher network stability
- Covering load and production peaks
- Implementing stand-alone networks for greater autonomy
- Protection in the event of blackouts
- Relieving the load on supply systems
- Optimizing consumption profiles

RENEWABLE ENERGY AND ENERGY STORAGE

- Classification of energy storage systems
  - Electrical energy storage
    - Electrostatic energy storage: capacitors, super-capacitors
    - Magnetic/current energy storage: Superconductor Magnetic Energy Storage (SMES)
  - Mechanical energy storage
    - Kinetic energy storage: flywheels
    - Potential energy: pumped storage, compressed air
  - Chemical energy storage
    - Electrochemical energy storage
    - Chemical energy storage
    - Thermochemical energy storage
  - Thermal energy storage
    - Low temperature energy storage
    - High temperature energy storage

Energy storage applications into the grid



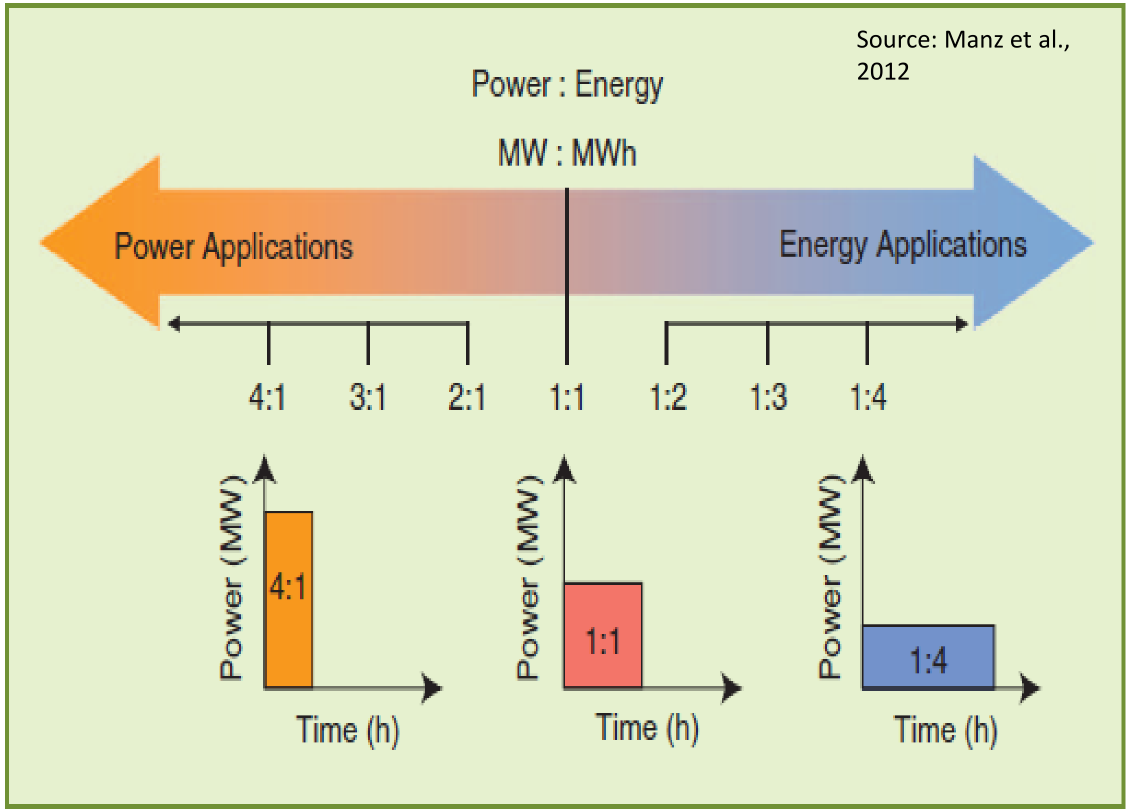


RENEWABLE ENERGY AND ENERGY STORAGE

- Continuous supply of quality power through renewables can only be ensured through the incorporation of battery storage systems in the setup
- Energy storage is one of many tools for aligning non-dispatchable renewable energy generation with load demands
- Wind and solar energy are available when weather dictates - not on command => Generation does not necessarily correspond to demand
- The reverse challenge arises from energy generated when load demand decreases

RENEWABLE ENERGY AND ENERGY STORAGE

- Technologies for storage can be viewed as either primarily power technologies or primarily energy technologies
  - Power-to-Energy ratio >= 2:1
    - Power Technologies
  - Power-to-Energy ratio <= 1:2
    - Energy Technologies



Applications of energy storage

	Application	Description	Value	Type
Applications for Energy Storage	Financial Energy Arbitrage	Buy low, sell high	Displaces most expensive generation	Energy
	Generation Capacity	Contribute to adequacy/reserve margin requirement	Defers investment in new generation	Energy
	Equipment Capacity	Reduce flow through overloaded lines and transformers	Defers investment in new equipment	Energy
	Line Congestion	Time shift delivery of renewable energy during congestion	Delays transmission line reinforcement	Energy
	Wind and Solar Power Smoothing	Reduce ramp rates of wind and solar plants	Contributes to reserve and regulation requirements	Power
	Frequency Regulation	Rapidly inject and remove power for short intervals	Contributes to regulation requirements	Power
	Spin and Non-Spin Reserve	Dispatch power in <10 min	Contributes to system reserves	Power
	Governor/Inertial Response	Provide dynamic functional equivalents of synchronous generators	Reduces severity of frequency excursions events	Power
Ancillary Applications for Energy Storage	Power Quality/ Harmonics	Suppress system harmonics	Contributes to power quality	Both
	Black-start	Support system during system restoration	Contributes to system black-start capability	Both
	Voltage Regulation	Manage delivery of reactive power to maintain voltage	Reduces need for new reactive power sources	Both

THE NEED FOR STANDARDS

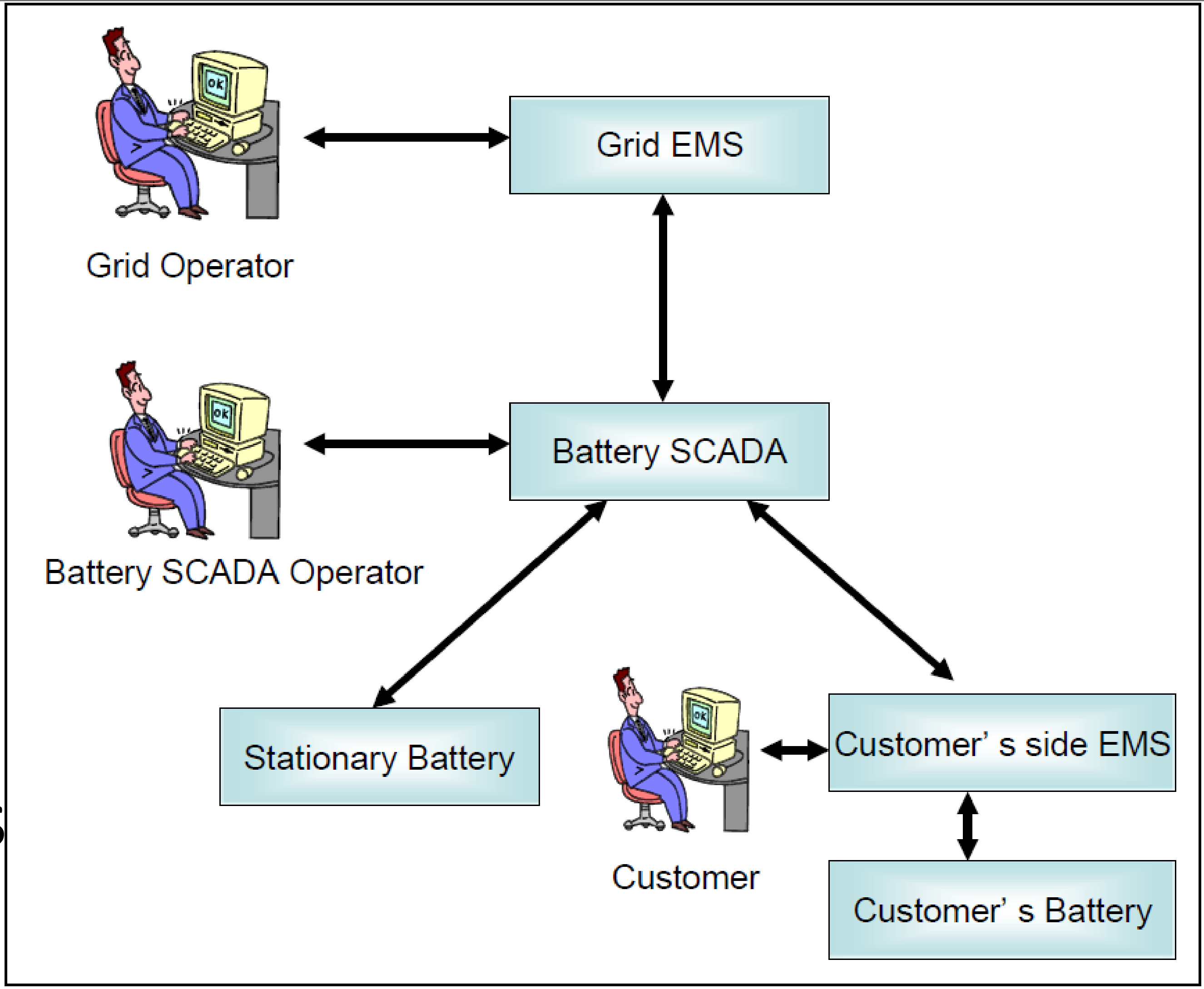
- Intelligent energy dispatching systems have been implemented in the power grid for control and data access
- Some of the technologies that are nowadays integral part of modern grid systems include:
  - Wide area measurement systems
  - Grid condition monitoring systems
  - Distribution automation systems
  - Mobile operational applications for condition-based maintenance
  - Advanced metering infrastructure
  - Geographic Information Systems

THE NEED FOR STANDARDS

- Interconnected grid systems are fully integrated with Information and Communication Technologies (ICT) in order to allow information exchange between various data centers and to controlling grid assets
- Standards and protocols should be defined and enforced such that grid operators from various regions maintain the same nomenclatures and terminologies
- Industrial Control Network (ICN) standards and protocols
  - NERC-CIP
  - ISO/IEC 27002:2005
  - NRC Regulation 5.71
  - NIST SP 800-82

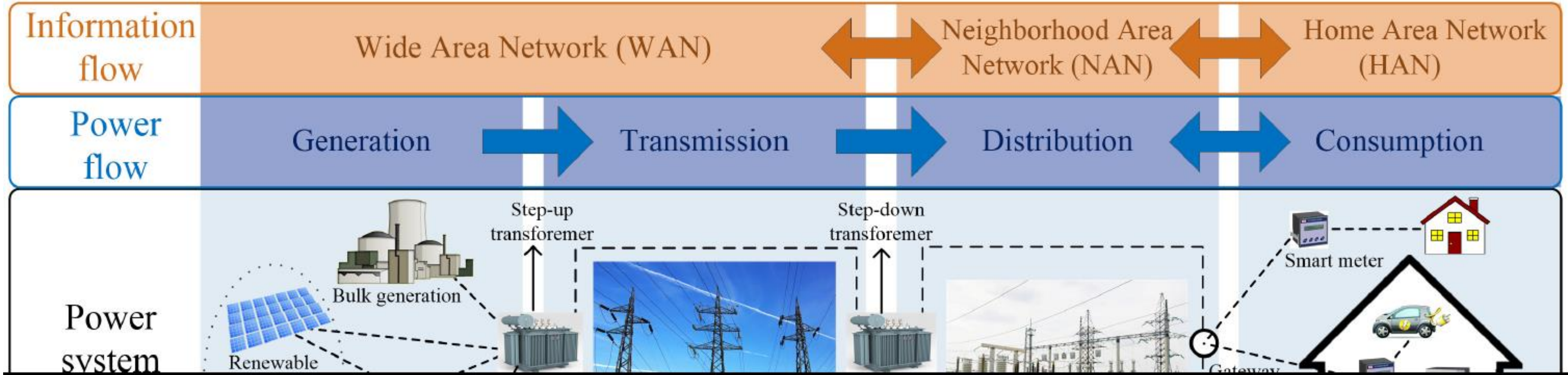
THE NEED FOR STANDARDS

- Modern electrical grid systems embody all the characteristics of a distributed network
- Ubiquitous information exchange and better awareness of energy availability and load profiles are essential



THE NEED FOR STANDARDS

Cyber-physical systems extending from generation to consumption and facilitating the integration of distributed storage



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THE NEED FOR STANDARDS

- Interoperability
  - Interoperability addresses the open architecture of technologies and their software systems to allow their interaction with other systems and technologies
  - Interoperability is often hampered by the differences in the data types, communication protocols, and middleware technologies used by the components involved

Deloitte, 2015

THE NEED FOR STANDARDS

- ❑ Standards ensure operation and maintenance of the system and associated equipment is improved, with greater efficiency, safety and reliability
- ❑ Standards are designed to ensure systems are safe to implement and operate, reliable, easy to troubleshoot, and efficient
- ❑ Communication is key for Energy Storage to function within the Smart Grid
  - ❖ Protocols, data models and semantic information models must be available to make full use of the potential benefit of Energy Storage
  - ❖ Communication must be available for the whole chain, power grid, power electronics, battery management (BMS), battery modules and cells.

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CONCLUSION

- No known document/website/publication that defines the cooperation between the power pools
- Technical planning of African grid interconnection should be properly carried out
- Conduct modeling/simulation studies at regional levels to assess the effects of distributed storage/generation on the grid
- Conduct modeling/simulation studies to assess the interplay between the various power pools

CONCLUSION

- Interconnecting and efficiently operating the African interregional grid seems to be challenging task: the scattered pattern of power stations and the wide spread area covered by the grid cause problems of load and frequency control
- Interconnected power systems requires a high degree of technical compatibility and operational coordination, which grows in cost, risks and complexity with the scale and inherent differences of the systems involved
- The African regional power pools should work together to follow the same standards for the electrical grid in order to ensure a seamless interconnection and interoperation