

“Wind Energy in Canada”

Fields Institute — November 1st, 2011

Bill Smith, SVP Energy Sector

Agenda

- 1** **Siemens Overview**
- 2** **Global Energy Perspectives**
- 3** **Canadian Energy Market**
- 4** **Innovations**
- 5** **Wind Forecasting**
- 6** **Thoughts for the Future**

Siemens – A Global Powerhouse

Energy

Divisions

- § Fossil Power Generation
- § Wind Power
- § Solar & Hydro
- § Oil & Gas
- § Energy Service
- § Power Transmission



Healthcare

Divisions

- § Imaging & Therapy Systems
- § Clinical Products
- § Diagnostics
- § Customer Solutions



Industry

Divisions

- § Industry Automation
- § Drive Technologies
- § Customer Services



Infrastructure & Cities

Divisions

- § Rail Systems
- § Mobility and Logistics
- § Low and Medium Voltage
- § Smart Grid
- § Building Technologies



€ 80''0 Business Volume – 405,000 Employees – ~5% R&D Investments

Siemens Energy Sector – Innovations and strategic decisions for energy over the last 140 years

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1892 First public three-phase power plant



1930 Expansion circuit-breaker



1964 First SF₆ circuit-breaker



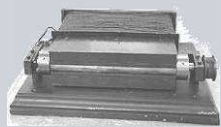
1989 Infinitely variable three-phase compensator



2008 World's First 800-kV HVDC



1866 Dynamo machine



1927 Benson boiler



2002 World record in combined cycle power plant efficiency



2008 Most powerful gas turbine 375 MW



1866

1900

1925

1975

2000

2008

1903 Siemens-Schuckert-Werke



1969 Trafo Union



1969 KWU



1998 Siemens Westinghouse



2001 Demag Delaval



2006 VA TECH T&D



2003 Alstom Industrial Turbines



2004 Bonus Energy



2007 Kühnle, Kopp & Kausch AG



2009 Archimede Solar

2009 Solel



Siemens Energy Sector – Newly focused on the markets of tomorrow

SIEMENS

Energy products and solutions – in 6 Divisions

Oil & Gas



**Keystone
Pipeline**

Fossil Power Generation



**York Energy
Centre**

Wind Power



**Comber
Wind Farm**

Solar & Hydro



**Thunder
Bay Airport
Solar Array**

Energy Service



**Bruce
Steam
Turbines**
Energy Sector

Power Transmission



**Nanticoke
SVC**

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Megatrends to 2050 – shaping the future

Urbanization



Urban populations will double to 6 billion

Demographic change



Average age worldwide will increase from 26 to 38 years

Climate change



CO₂ productivity must grow by factor of 15 to prevent temperature rising more than 2°C

Globalization

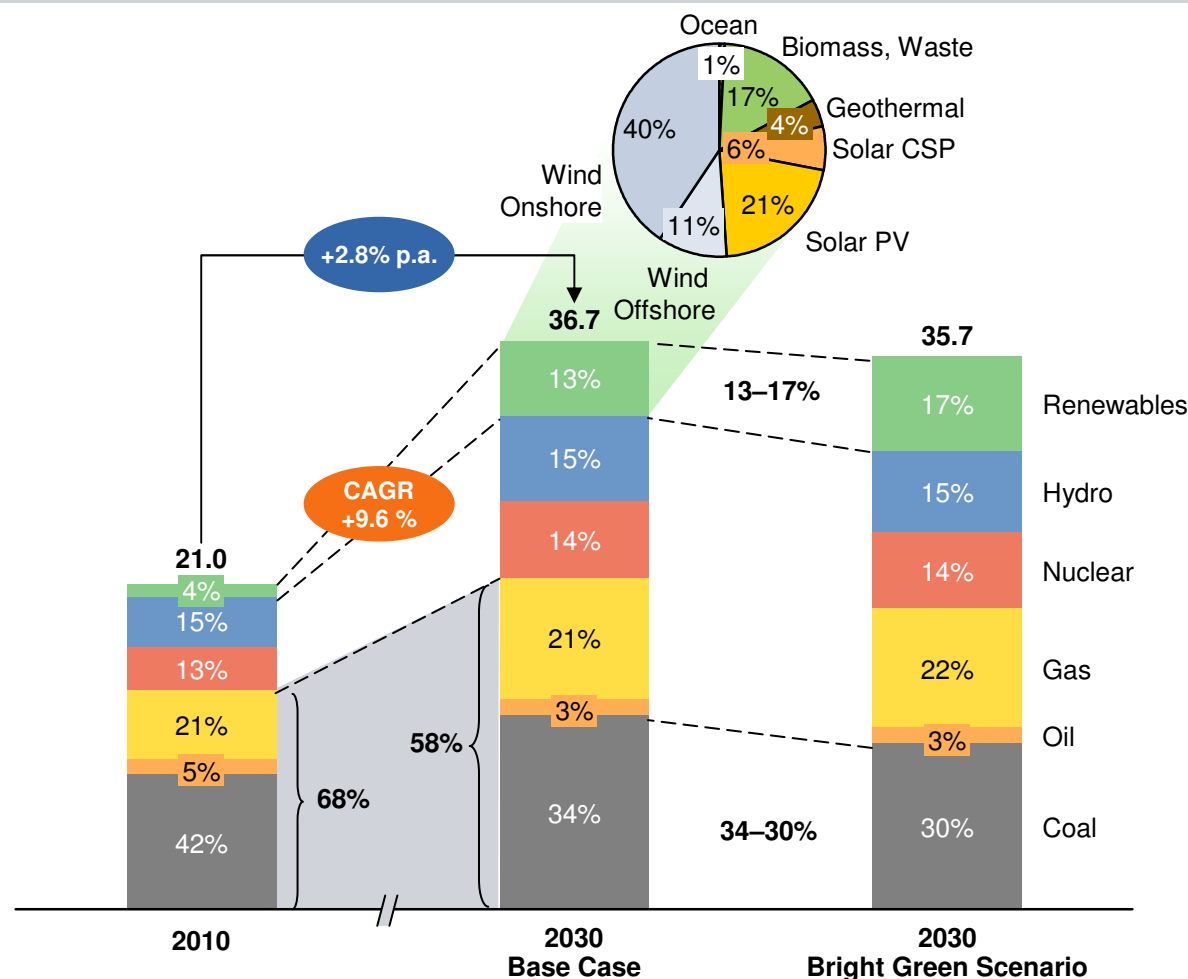


BRIC countries will contribute 50% of global economic growth

Source: United Nations, The Lancet, Climate Works/European Climate Foundation, Economist

Trends in power generation – Two possible scenarios

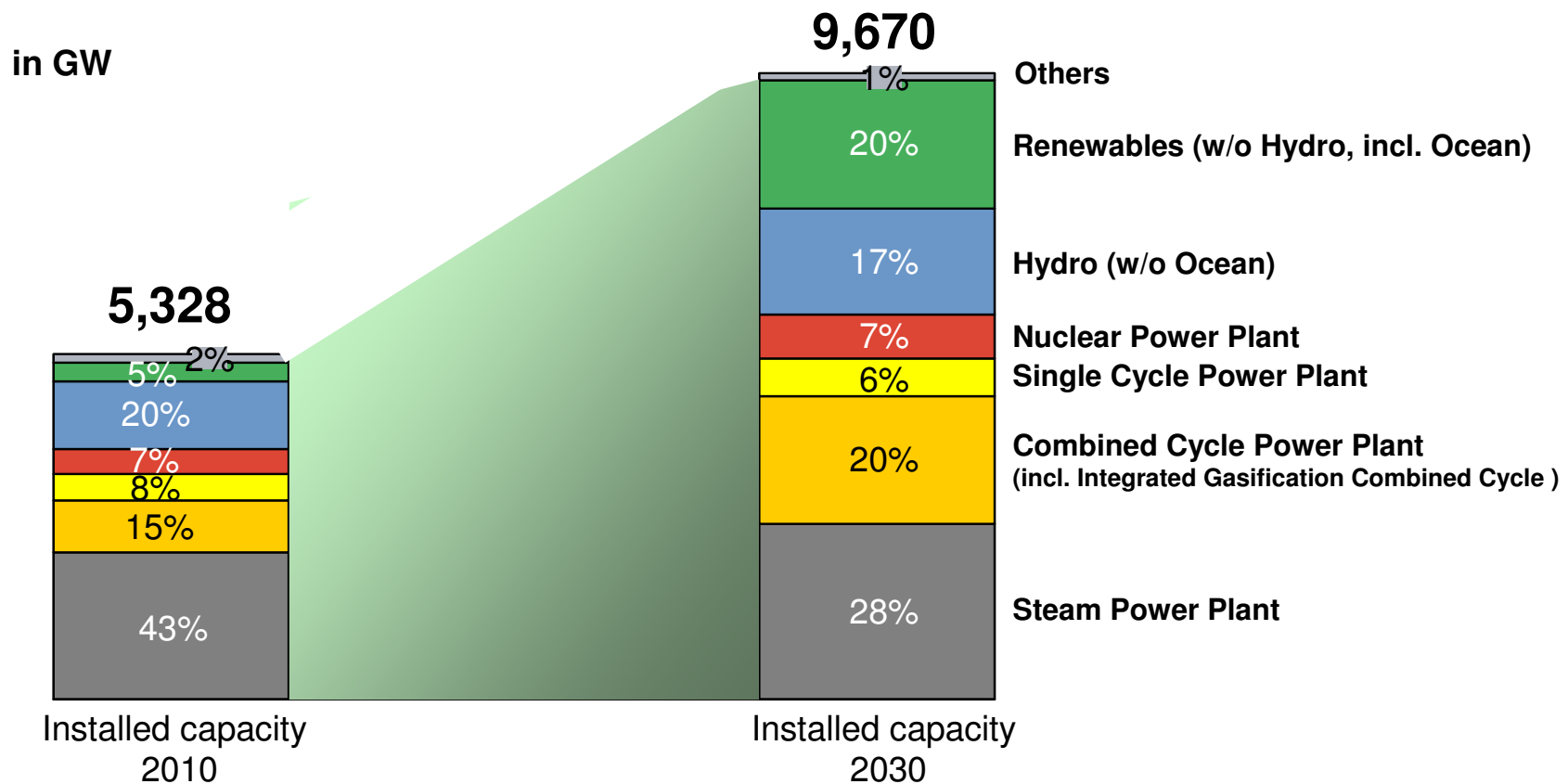
SIEMENS



Source: Siemens

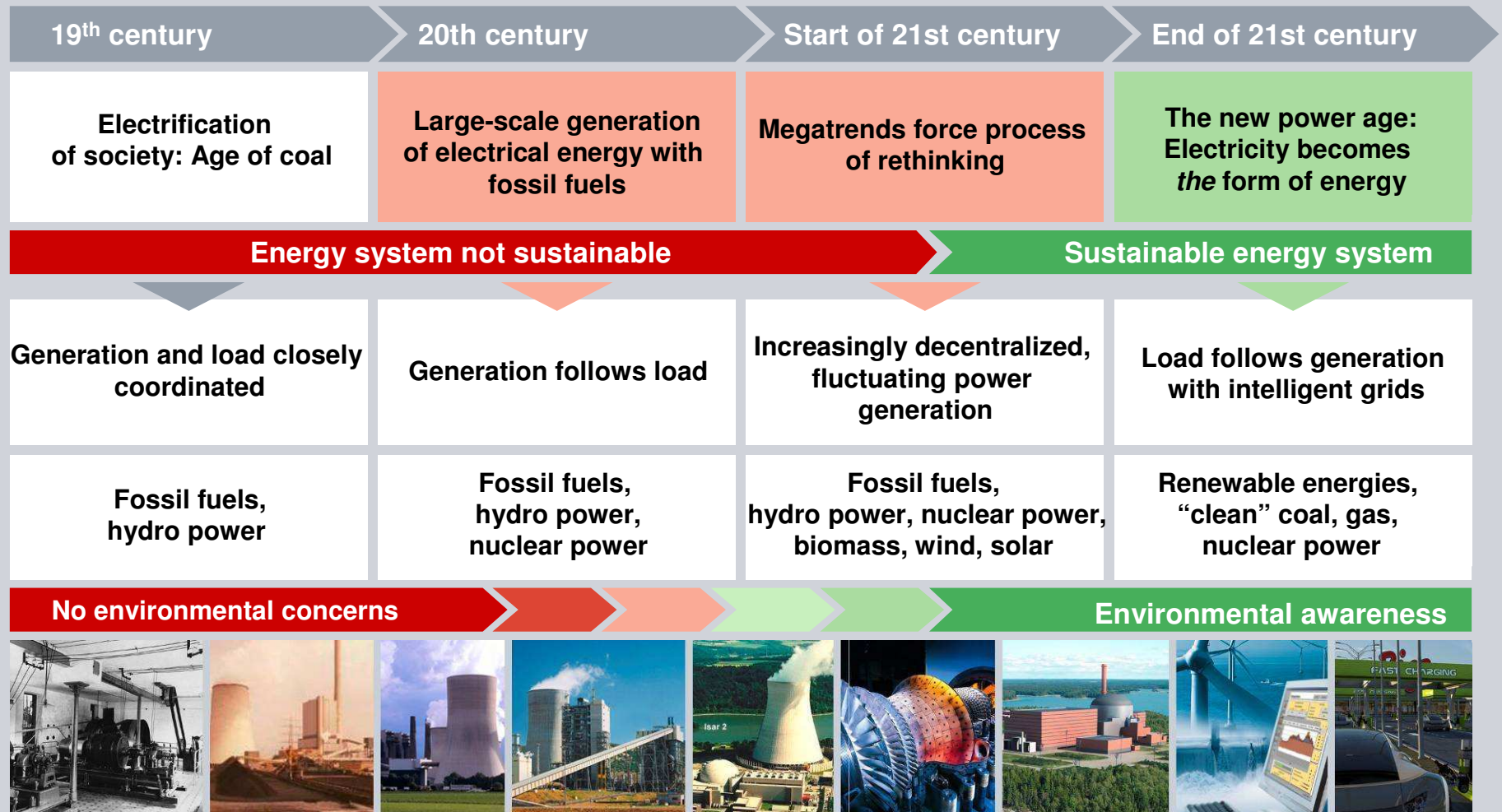
Energy demand – Doubling the installed capacity by 2030

Development of world power plant capacity within the next 20 years



Power generation capacity built in > 100 years to double within two decades

On the way to a sustainable energy system



Agenda

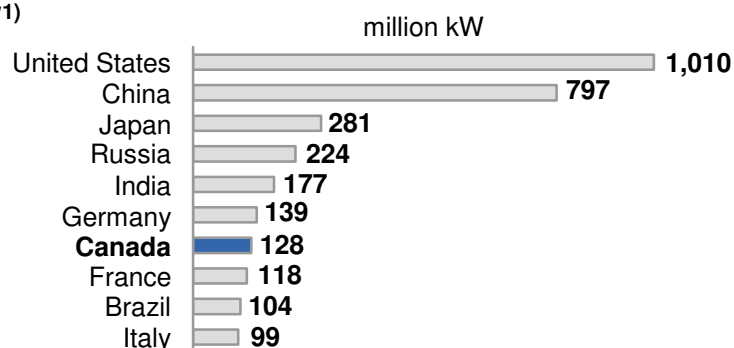
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Canada is world's #7 energy producer, and one of its greatest users per capita

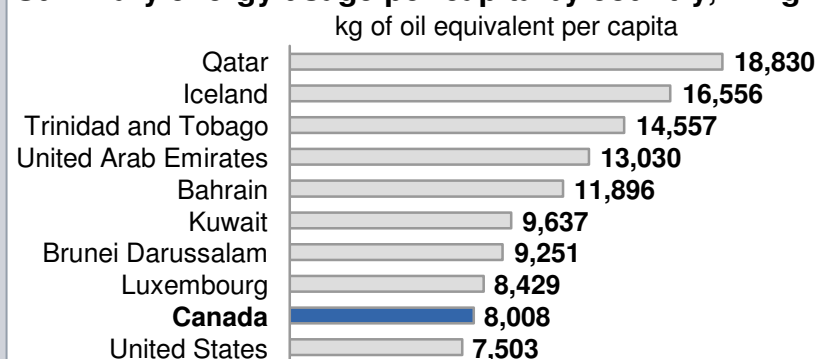


Canada macroeconomic snapshot

Summary of energy generation capacity by country, M kW¹⁾



Summary energy usage per capita by country, in kg ²⁾

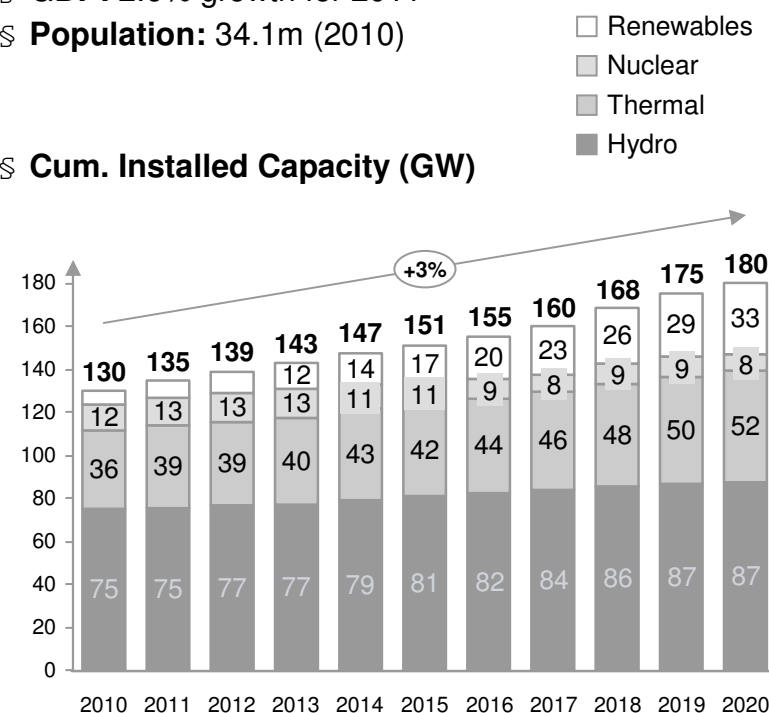


Key statistics

§ **GDP:** 2.6% growth for 2011³⁾

§ **Population:** 34.1m (2010)

§ **Cum. Installed Capacity (GW)**



1) EIA International Energy Statistics data as of 2008

3) "Global Forecast Update" Scotiabank Group, 2011-08-05

Source: CAN E Market Transparency Project

2) IEA data as compiled by the World Bank

4) Statistics Canada, CANSIM, table 052-0005 and Catalogue no. 91-520-X.

Canadian energy market is heavily influenced by politics in Canadian provinces and US exports

Theresa to refine further

PEST analysis of Canada's energy market

Political Factors



- § Canadian **provincial and federal government push renewable energy – esp. wind**; continued investment depends on continuation of renewable incentive programs
- § Political instability in the in OPEC nations may create a **surge in demand for Canadian oil**
- § Canada exports oil and electricity to the US and its markets are therefore **tied to US policy**

Economic Factors



- § **Stable financial institutions** create positive investment climate
- § **A weak global economy may delay or postpone** future energy projects
- § **Increased competition** in several segments (transformers, solar, wind) have **driven prices down**
- § **Strong dollar** prolongs difficulties in manufacturing sector
- § Free trade agreements with EU and Brazil **may shift trade balance**

Social Factors



- § **Renewables programs** established at provincial level
- § Call for **regulation of coal-fired** generation across Canada
- § Urbanization in Canada increased from 15% to 40% between 1978 and 2008, **driving urban demand for electricity**
- § Workforce demographics and supportive immigration policy are creating **highly diverse workplace**

Technological Factors



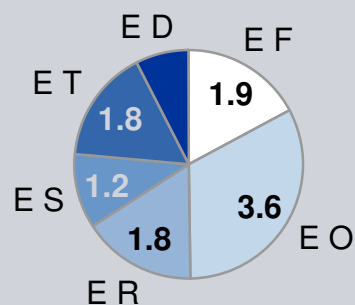
- § Canada's **aging energy infrastructure** requires maintenance to continue operation
- § Generation investments will focus on **efficiency and lowering environmental footprint**
- § **Demand management programs** in selected provinces are creating incremental investment in transmission and distribution systems
- § **New market players enter** the Canadian energy market **with new innovations**

Ontario, Alberta, Quebec, BC are the top 4 energy markets in Canada – Wind is Growing Fastest

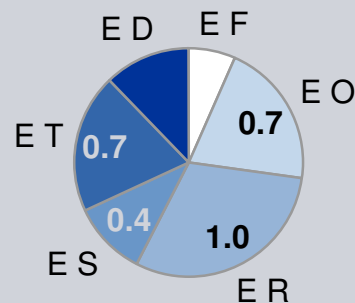
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Top Canadian markets by total addressable market (2011-2016, EUR)

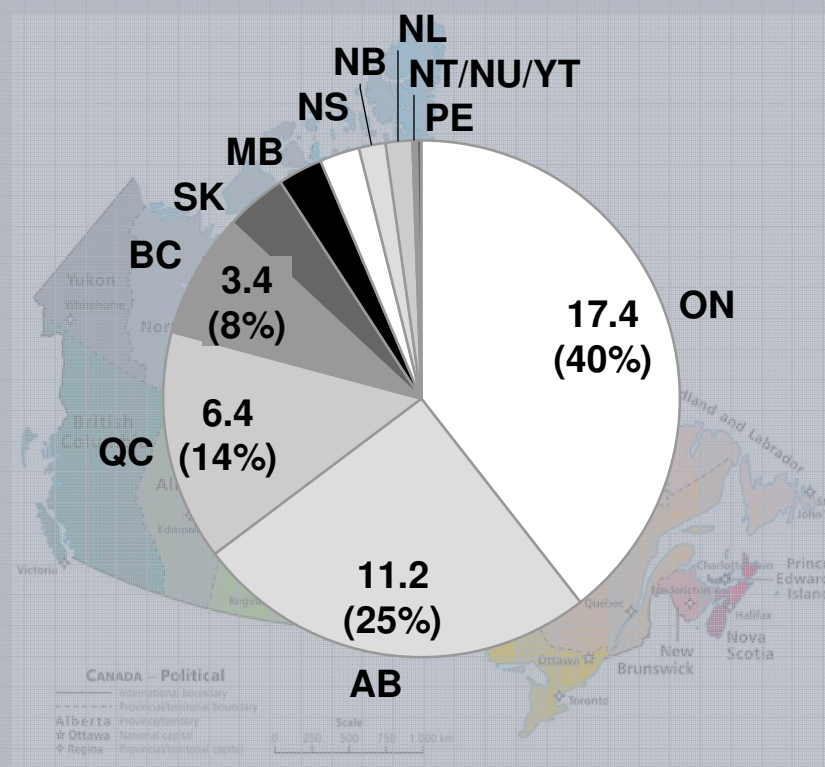
#2 Alberta: €11"2 (25%)



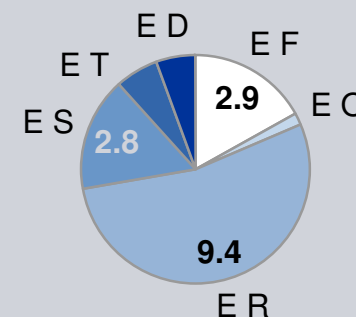
#4 BC: €3"5 (8%)



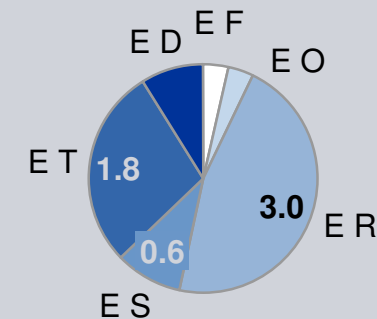
Addressable Energy Market in Canada
€44" (2011-2016)



#1 Ontario: €18" (40%)



#3 Quebec: €6"8 (14%)



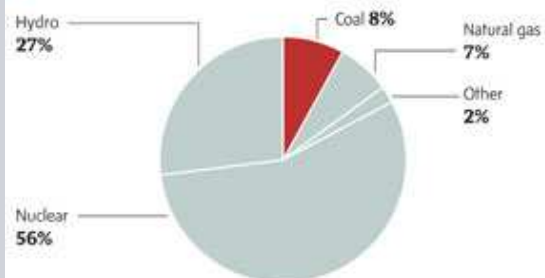
Alberta and Ontario are main greenhouse gas producers

Power & greenhouse gas production: Ontario vs. Alberta

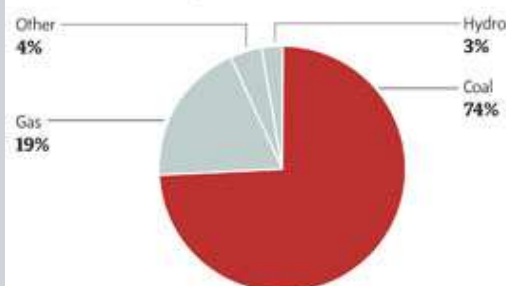
BEHEMOTHS COMPARED

WHERE THEY GET THEIR POWER

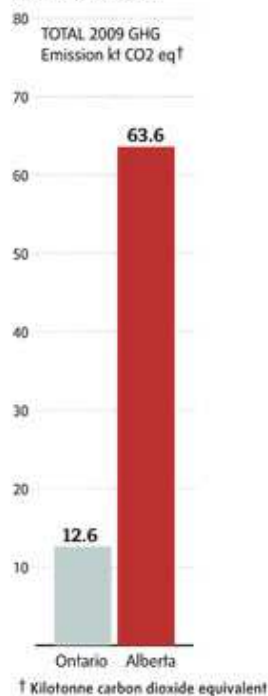
➔ ONTARIO, 2009: **144,400 GWh**



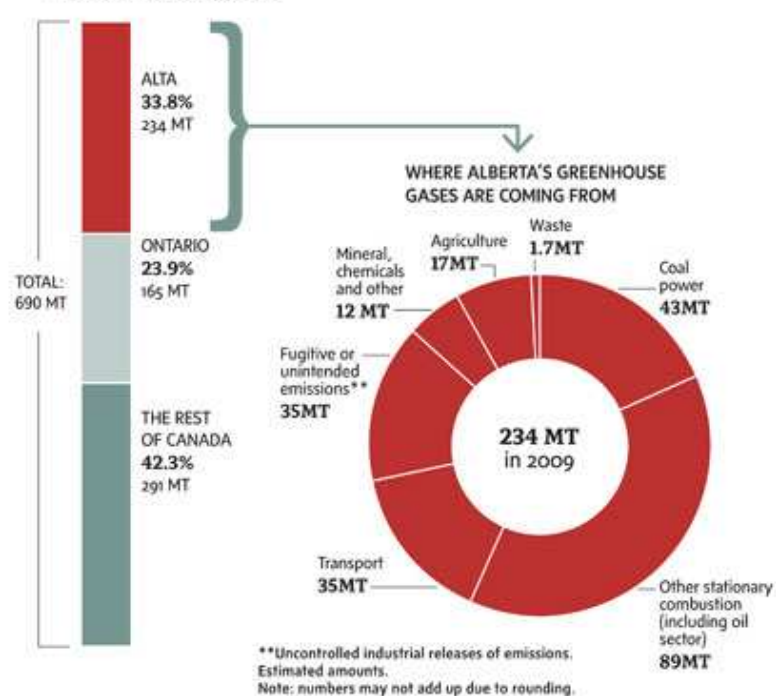
➔ ALBERTA, 2009: **54,000 GWh**



PER CAPITA GREENHOUSE GAS PRODUCTION



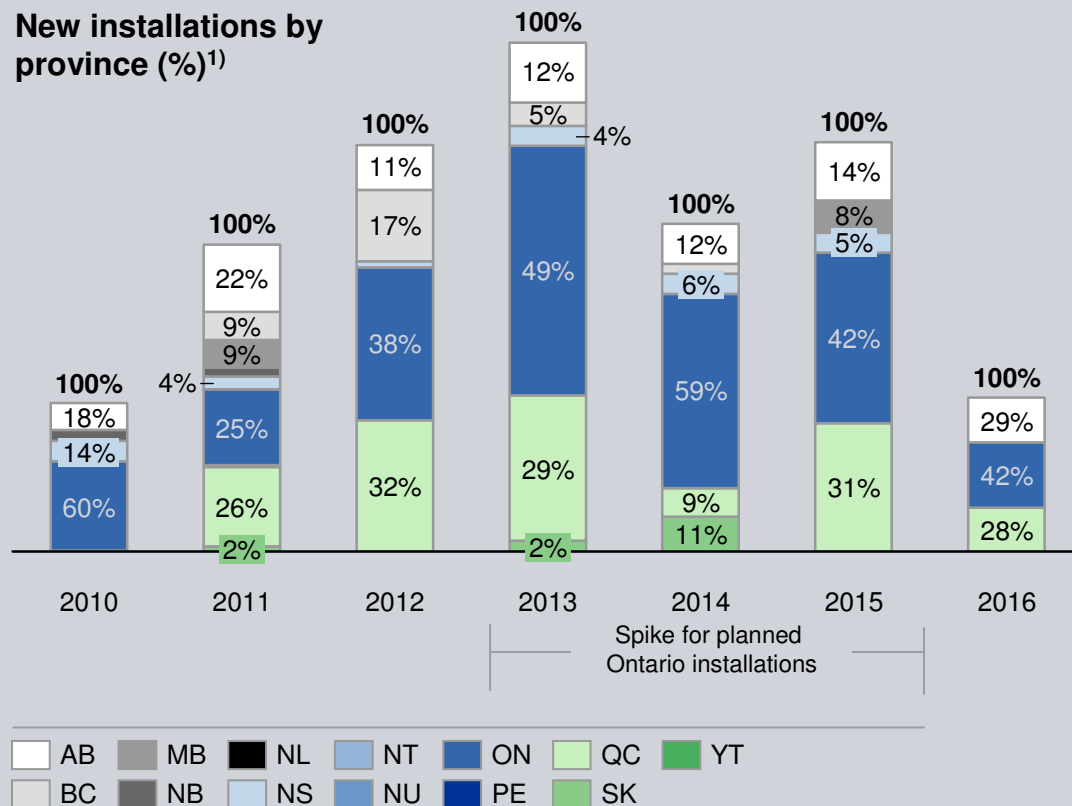
2009 GREENHOUSE GAS PRODUCTION, IN MEGATONS



Market spike expected in 2013

Clarification on provincial nature of Canadian wind markets

New installations by province (%)¹⁾



Implications / recommendations for E W

- 1 Alberta** merchant market, price competition, carbon offsets
- 2 Quebec:** Concluding entail offering, second tranche of installations expected, complimentary to large hydro
- 3 Ontario:** FIT program is pioneering clean development,
- 4 Atlantic Canada** Comfit on Nova Scotia, simultaneous development with Lower Churchill

1) Absolute values being aligned as part of MEP / SR2012

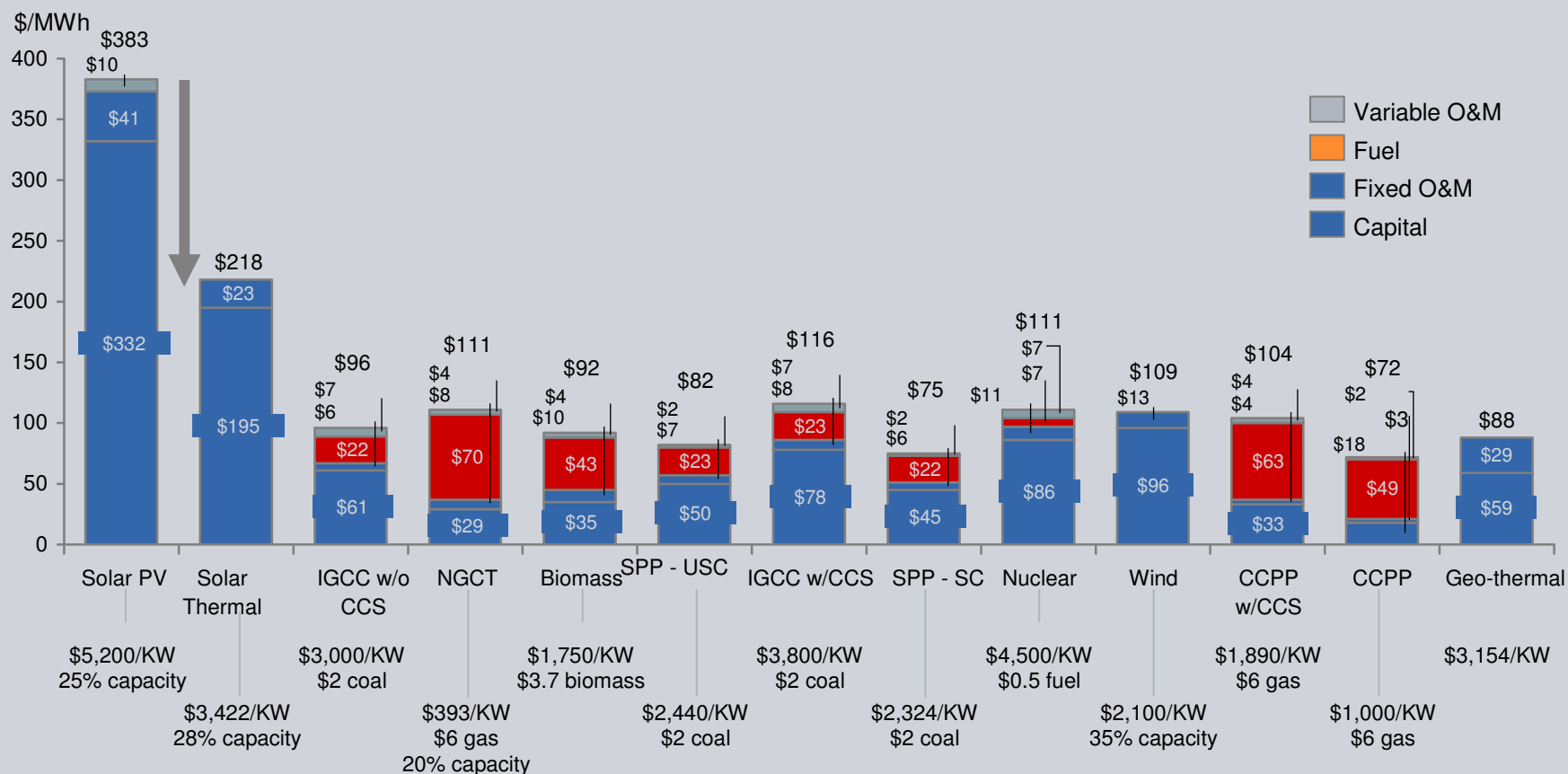
Source: CAN E Market Transparency Project, Canada Wind Power Outlook 2010 to 2020 Global Data Research, July 2011, CanWea, NRCan, IESO Long term plan 2011, IESO

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Economics and Technology

Generation LCOE Comparison — (without Carbon Pricing)

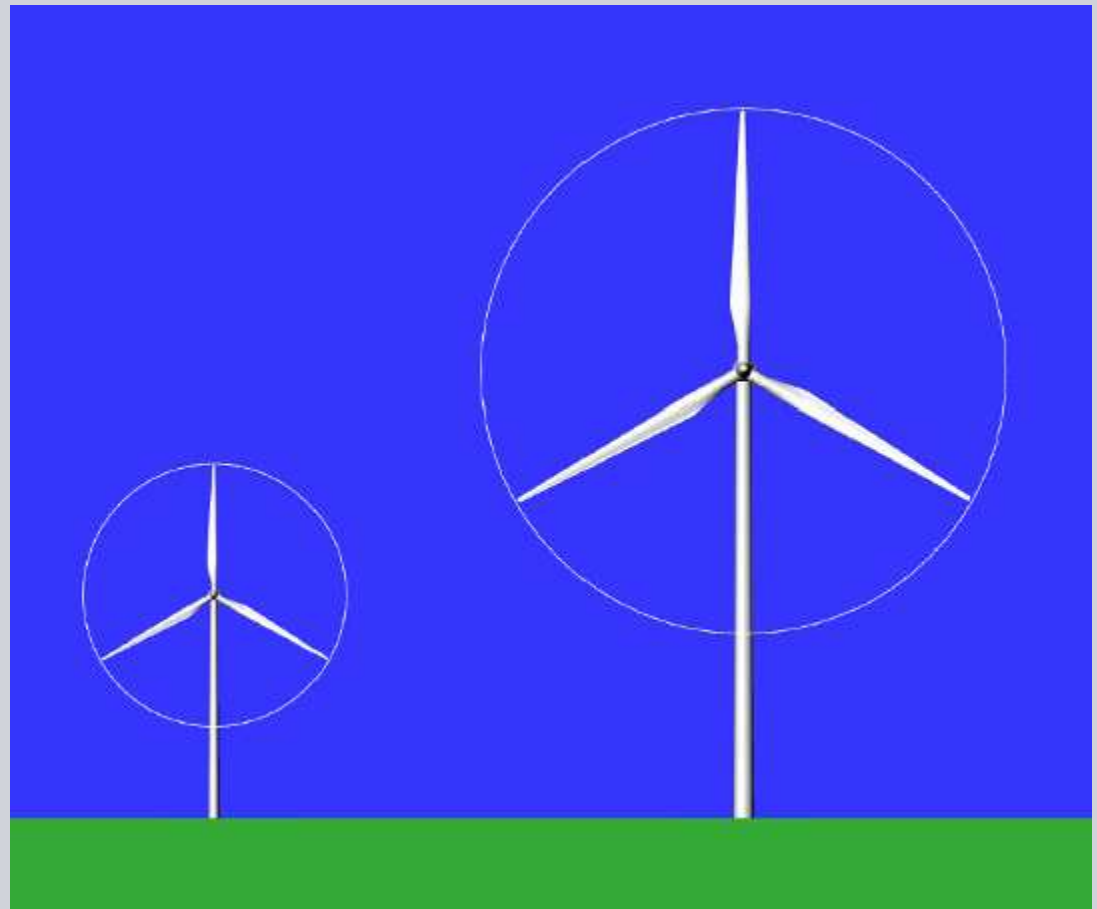


Note: Assumed cost of equity of 12%, cost of debt 7.5%, 55% debt and escalation of 4.5%; general inflation rate of 2.5%; analysis excludes tax benefits; assumes baseload capacity if not stated. ICGG – Integrated Gasification Combined Cycle; CCS – Carbon, Capturing and Storage; NGCT – Natural Gas Combustion Turbine; USC – Ultra Super Critical; SC – Super Critical
 Source: EIA; multiple industry reports and company filings; Booz & Company analysis

What is the fundamental challenge?

The problem is the square cube law

- If we multiply all dimensions by two...
 - The blade length increases linearly with the scaling factor – the blade is two times longer
 - The rotor area increases with the scaling factor squared – the rotor area is four times larger
 - The volume of the equipment increases with the scaling factor cubed – the weight is eight times larger
- In other words, when we double the size, we get four times as much energy, but have a machine that is eight times heavier



The Fundamentals of Competition

$$LCOE = \frac{\sum_{t=0}^n \frac{\text{Investments}_t}{(1 + WACC)^t} + \sum_{t=0}^n \frac{\text{O\&M Cost}_t}{(1 + WACC)^t}}{\sum_{t=0}^n \frac{\text{Energy Output}_t}{(1 + WACC)^t}}$$

Generation Cost

Generated Electricity

LCOE considers costs and electricity generation over the whole lifetime of a power plant

- **Reduction of investment**
 - WTG investment
 - BOP investment
- **Reduction of O&M Cost**
- **Increase of energy output**

The SWT-3.0-101 wind turbine with direct drive technology is designed for low cost of energy

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SWT-3.0-101 wind turbine generator

IEC Class:	IA
Rotor diameter:	101 m
Blade length:	49 m
Swept area:	8,000 m ²
Hub height:	80-100 m
Power regulation:	pitch regulated, VS
Annual output at 8.5 m/s:	12.4 GWh ¹⁾
Blade weight:	10.3 tons
Rotor weight:	60 t
Nacelle weight:	73 t
80 m tower weight (IEC IIB):	170 t
Serial production:	2011
Total number installed:	5 ²⁾
Units ordered:	25



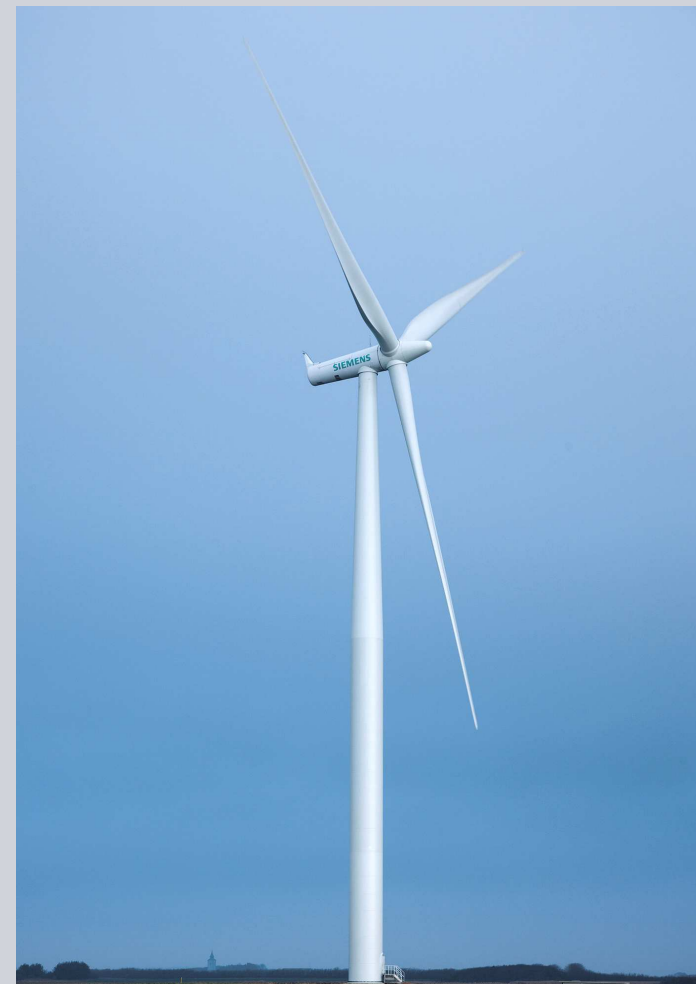
1) Power curve revision 1 2) June 2011

The SWT-2.3-101 wind turbine optimizes your energy yield in moderate wind conditions

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SWT-2.3-101 wind turbine generator

IEC Class:	IIB
Rotor diameter:	101 m
Blade length:	49 m
Swept area:	8,000 m ²
Hub height:	80-100 m
Power regulation:	pitch regulated, VS
Annual output at 8.5 m/s:	10.5 GWh ¹⁾
Blade weight:	10.3 tons
Rotor weight:	60 t
Nacelle weight:	82 t
80 m tower weight (IEC IIB):	170 t
Serial production:	2009
Total number installed:	454 ²⁾



1) Power curve revision 2 2) June 2011

SWT-2.3-113: Direct drive turbine with 113 m rotor improved energy yield and acoustic performance

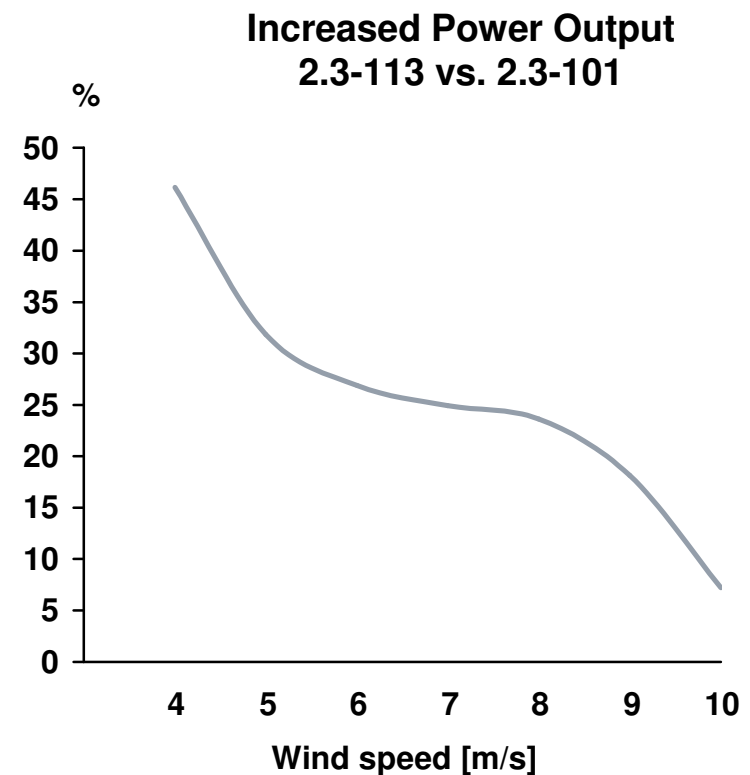
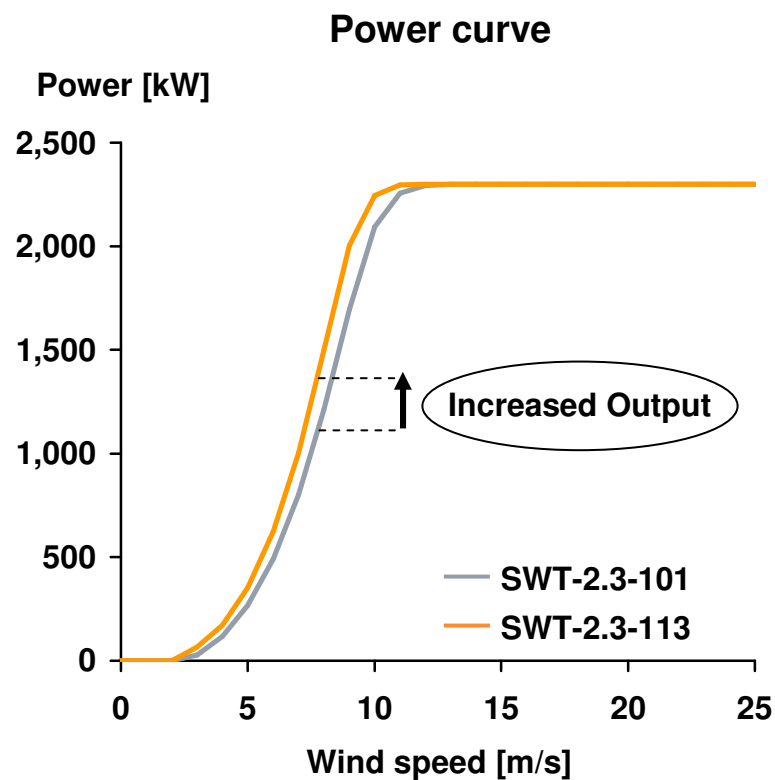
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Technical data

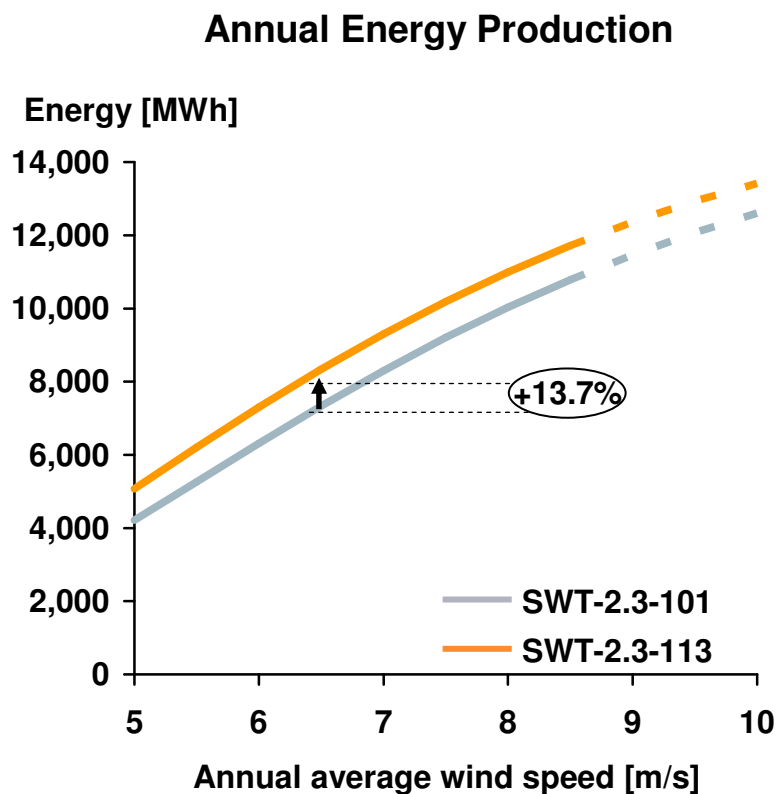
IEC class:	IIB / IIIA
Nominal power:	2,300 kW
Rotor diameter:	113 m
Blade length:	55 m
Swept area:	10,000 m ²
Hub height:	79.5m and 99.5m
Rotor weight:	67 t
Nacelle weight:	73 t
Power regulation:	Pitch regulation, variable speed
Prototype installed:	March 2011
Pilot series	2011
Serial production:	2012



SWT-2.3-113 Direct Drive: Enhanced Efficiency



SWT-2.3-113 Annual Energy Production (AEP) up 13.7%



SWT- 2.3-113	
Annual average wind speed [m/s]	AEP (kWh)
5.0	5,077
5.5	6,206
6.0	7,302
6.5	8,341
7.0	9,306
7.5	10,192
8.0	10,996
8.5	11,720
9.0	12,363
9.5	12,928
10.0	13,417

**The 2.3-113 has the same nacelle as the 2.3-101,
the main difference is in the generator winding**

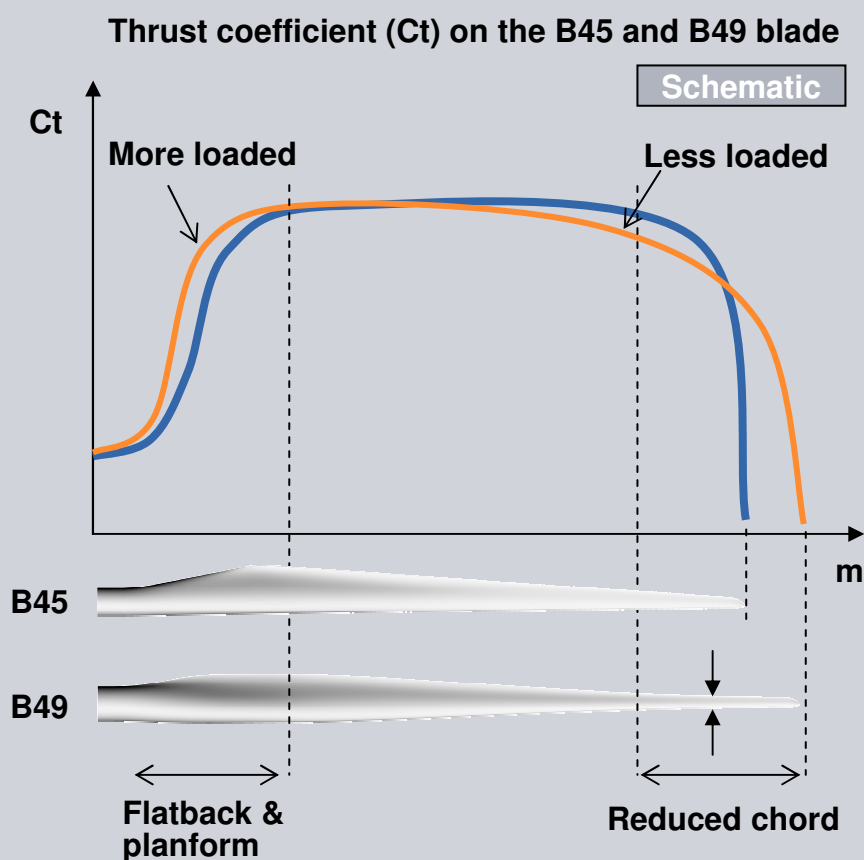
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- § Generator is dimensioned by torque
- § The 3.0-101 generator has 2000 kNm torque at 16 rpm
- § The 113 m rotor has a rotor speed of 13 rpm to keep down noise
- § At 2000 kNm and 13 rpm the power output is 2.3 MW
- § The 2.3-113 nacelle shares the same benefits as the 3.0-101 – simple, lightweight nacelle, direct access to hub, passive cooling system with liquid link, etc.



Evolution with a twist of revolution: 15% larger swept area with the same loads

4 Blade design: loads



New aerodynamic profile redistributes loads in the B49 blade, reducing the cumulative bending moment

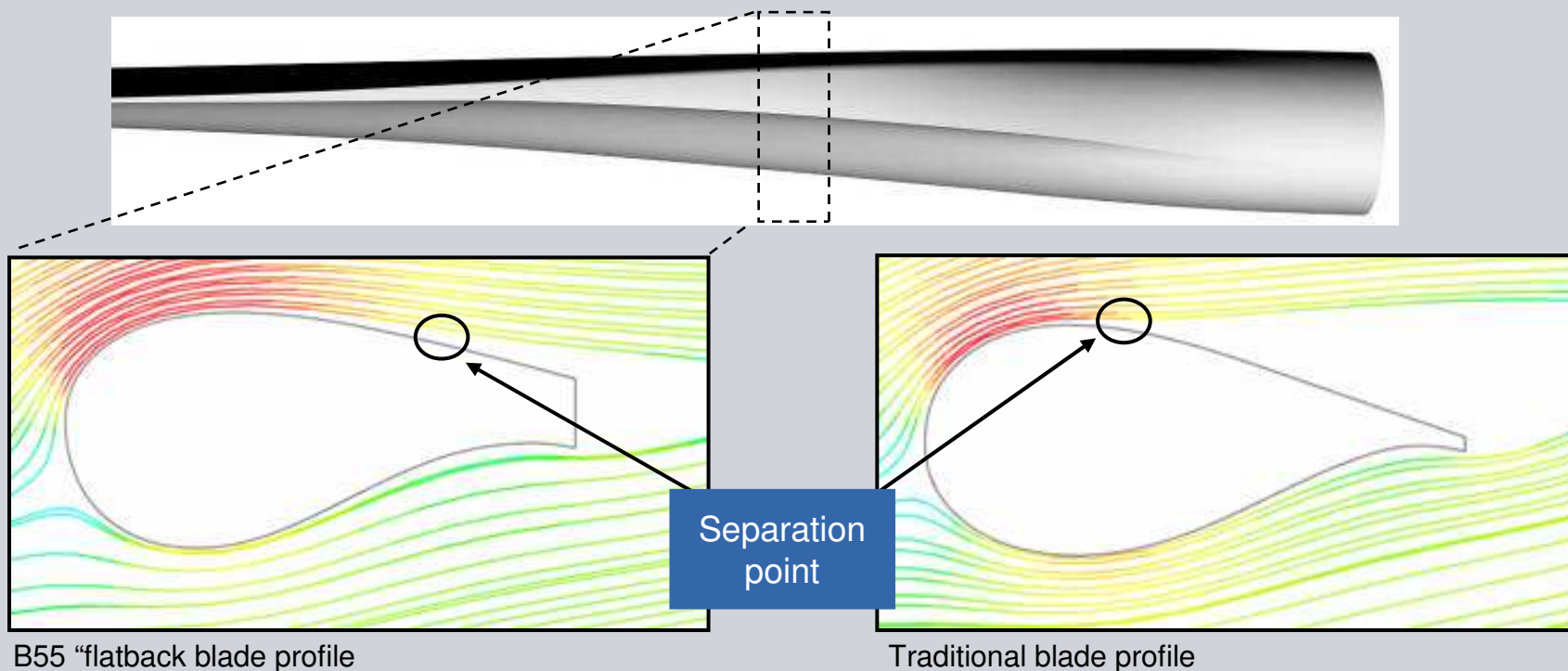
The root section is more heavily loaded due to the use of special flatback airfoils, and a larger planform (more chord)

The tip section is less heavily loaded due to reduced chord length

— B45
— B49

The new B55 has “flatback” profile in root section

4 Blade design: Root section



- § Flat back airfoil ‘opens up’ the trailing edge
- § Separation point moved further towards the trailing edge giving increased lift

Blade design innovation

First generation blade – B45 (2005)

- Linear leading and trailing edge
- Maximum chord at well-defined shoulder ~20% from root
- Airfoils from aircraft industry
- Inboard part generally with rudimentary airfoils

Quantum Blade I – B49 (2008)

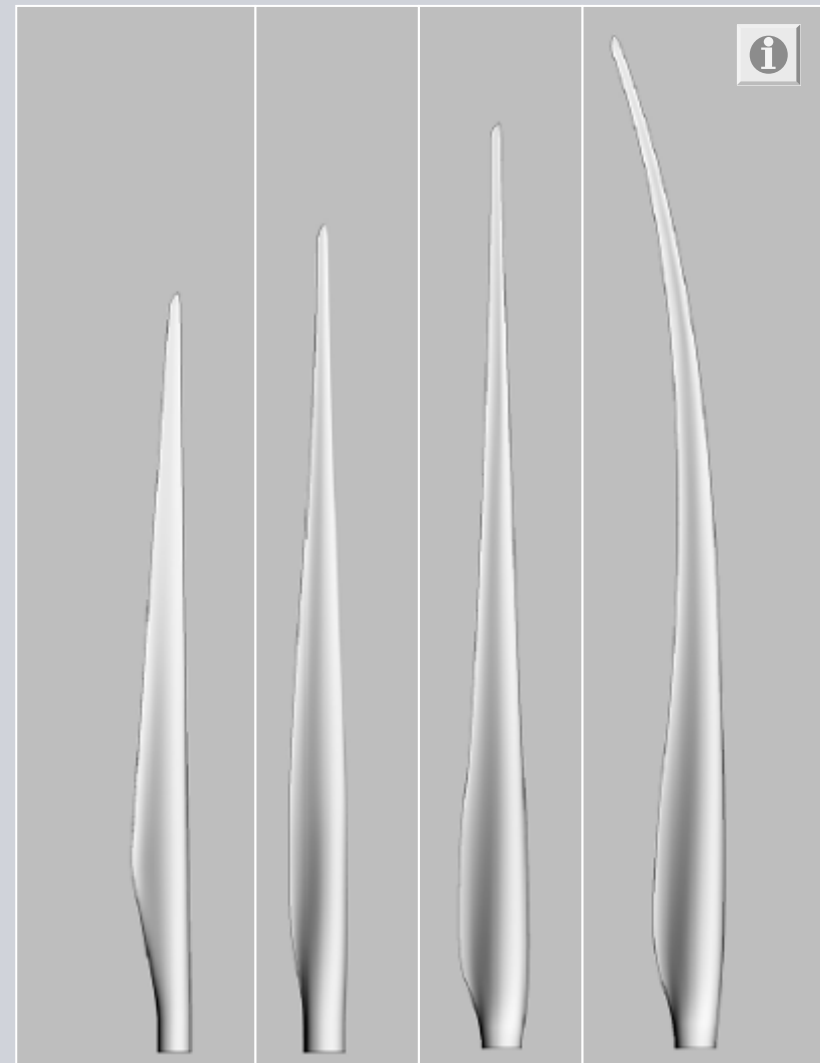
- Non-linear leading and trailing edge
- Proprietary flatback airfoils at root
- Load reduction by pressure centre moved closer to root
- Same loads as B49, 7-8 % more energy

Quantum Blade II – B55 (2010)

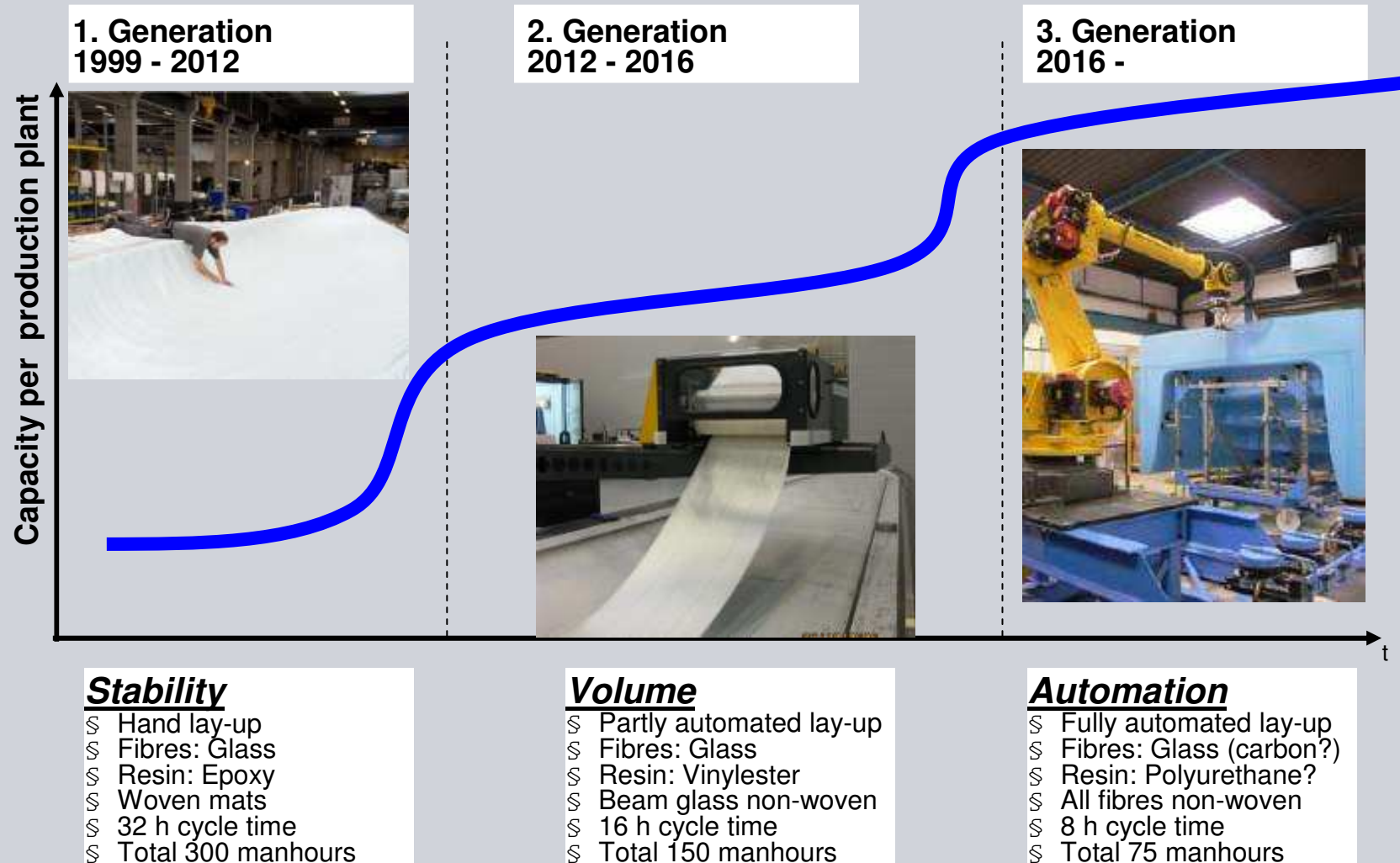
- Non-linear leading and trailing edge
- Shortened section of maximum chord, slender outboard part
- Load reduction enhanced by low weight and high flexibility
- Marginally higher loads than B49, 8-10% more energy

Aeroelastically Tailored Blade – B60 (2013)

- Curved planform
- Proprietary airfoils both at root (flatbacks) and outboard
- Load reduction by twist-bend coupling
- Same loads as B55, 8-10% more energy at low winds



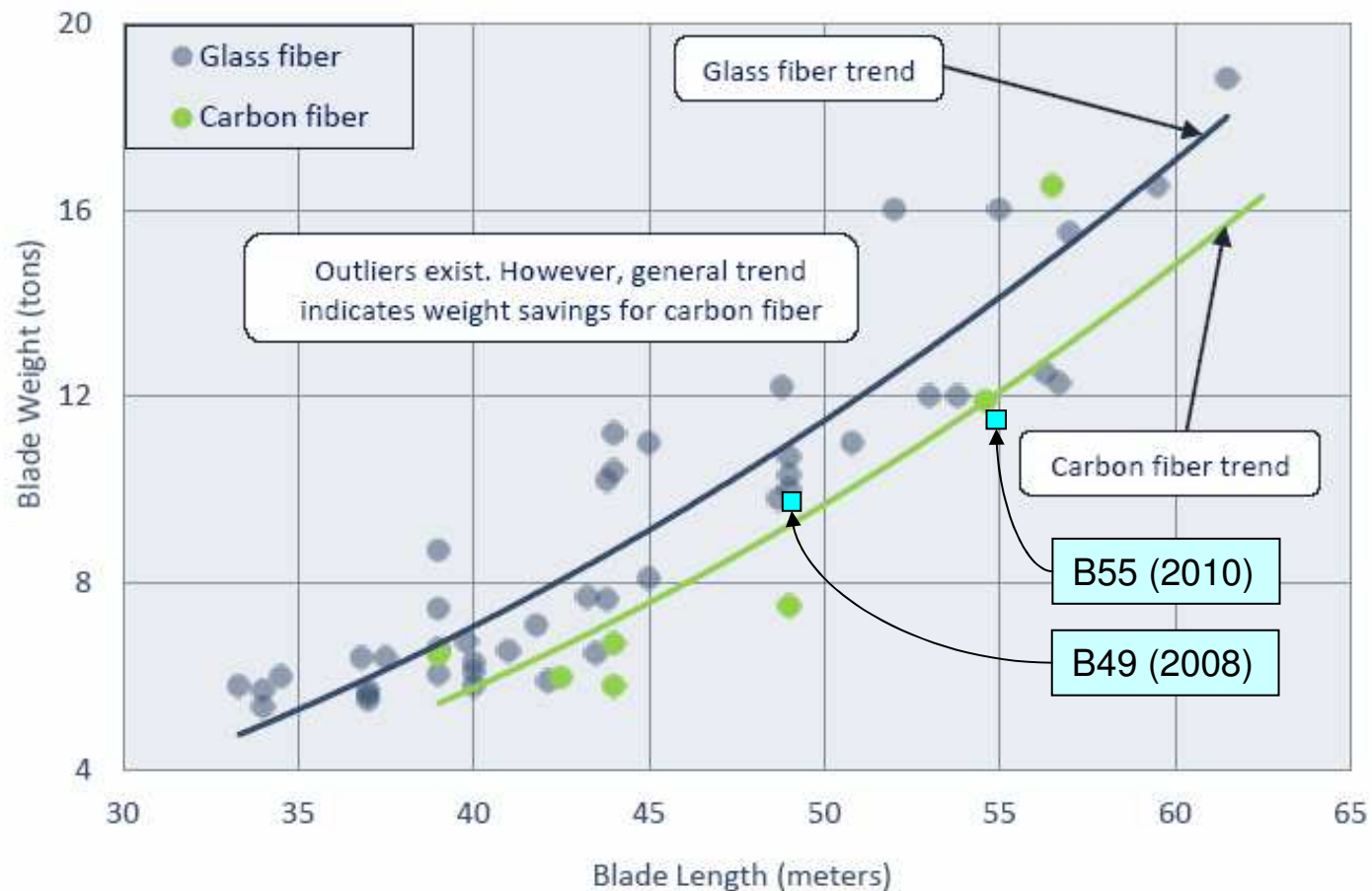
Blade manufacturing innovation



SWP “Quantum Blades” setting standard for low weight – using low-cost glass fibers, not carbon

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Figure 20 Blade Weight Trend



Note: Trend lines plotted using Power regression
Source: MAKE Consulting

Blades summary – Larger Rotor Diameters have been developed and are being tested today

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Merger of aerodynamics, loads and structural response into aero-elastically tailored blade

- Next generation blade configuration on the way
- B49 and B55 already with state-of-the-art performance and weight

Quantum-leap optimization of blade manufacturing initiated

- First generation manufacturing maintained since commencement of insourcing
- Second generation promises reduction of lead time and man hours per blade by 50%
- Third generation in pipeline, will take automation of blade manufacturing to next level

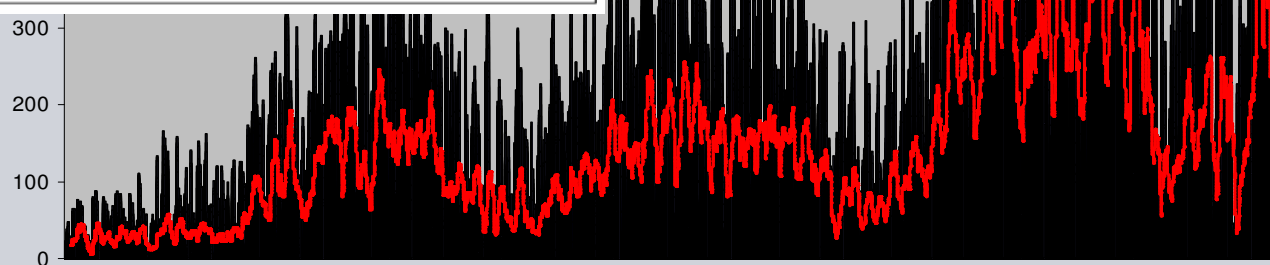
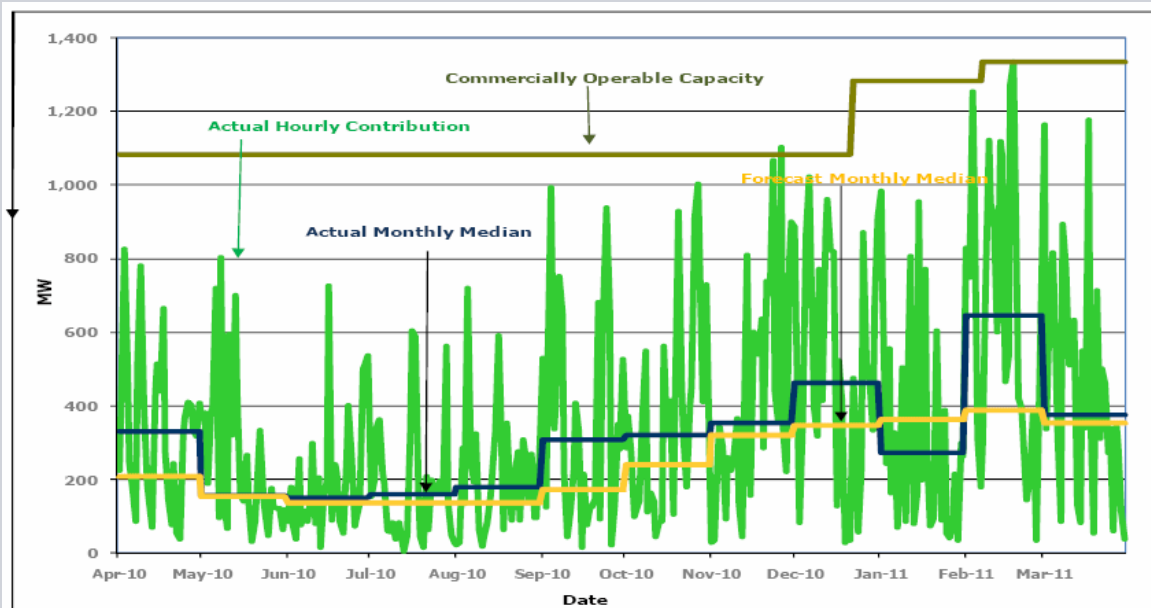


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The Challenge with Integrating renewables

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Forecasting tools, digital controls deploying smart algorithms, combined with flexible load following capability plus storage at MW scale

Collaboration with Lawrence Livermore National Labs analyzed potential groundbreaking approach

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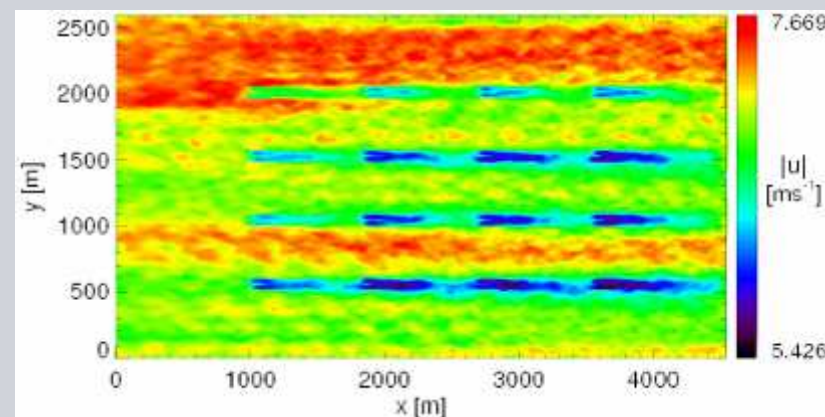
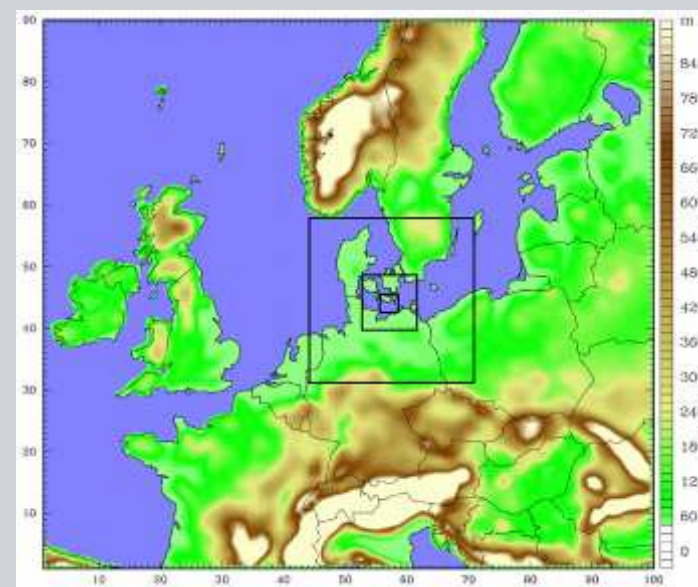
Project Setup (2009-2011):

- § Building a team of professional meteorologists
- § Comprehensive wind energy prediction system
- § Research based on offshore wind farm in Denmark

Deliverables:

1. Ensemble forecast platform
2. Cutting-edge data assimilation tool
3. Predictive turbine wake model (unique to Siemens)

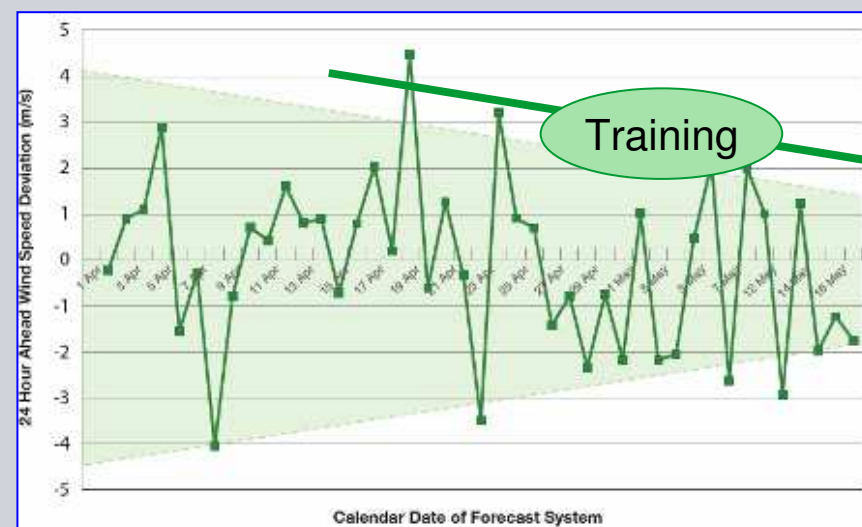
Project concluded with advanced prediction algorithm, ready for validation across different wind farms



Promising research results currently tested on various wind farms to verify forecast accuracy

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- § Technology validation in collaboration with commercial supplier of forecasting solution
- § Leveraging Siemens' access to turbine-data and knowledge about turbine dynamics to improve forecasting accuracy by intelligent prediction
- § Three wind farms connected to forecasting system (onshore simple, onshore complex, offshore):
 - § Training and fine-tuning of forecasting algorithms
 - § Optimization of user interface and communication interfaces with wind turbines



Tailoring of forecasting solutions to customer segments important to maximize value add

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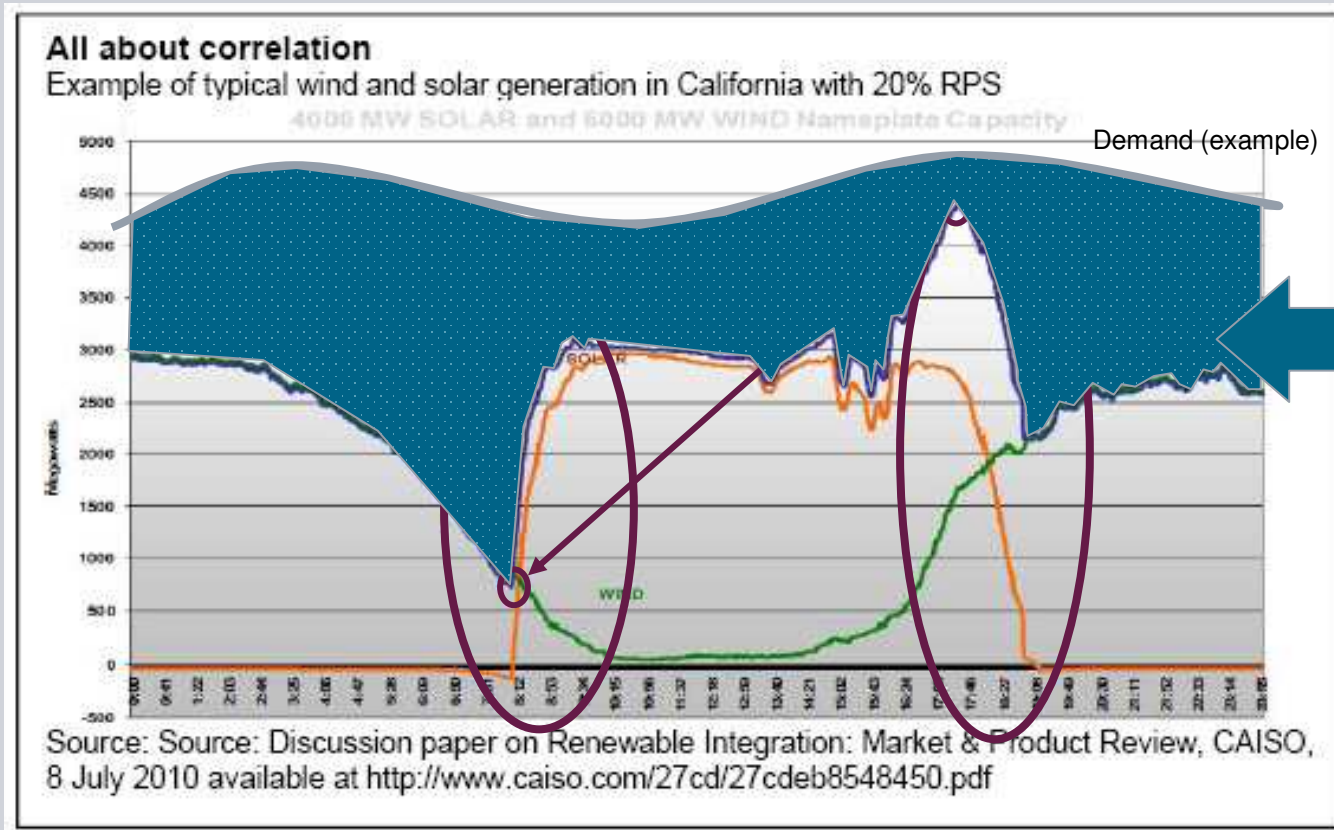
- § Several customer groups will benefit of improved forecasting
 - § Wind farms owners
 - § Power utilities
 - § TSOs & ISOs
 - § Windfarm service providers
- § Features of Siemens' product suite will be tailored to needs of selected customer groups
- § Further development focuses on integration of critical events (lightning, icing, wind-ramps, offshore: wave height)



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The Challenge with Integrating renewables



1. Fast Ramps up and down
2. Large changes in power supplied

This is the shape of power that is needed

For this example, this is the shape of power that must be available to fully enable your renewables

The Gas Turbine Evolution from the SGT6-5000F to the SGT6-8000H

High Efficiency
4-Stage turbine section

Ultra High Efficiency
4-Stage turbine section

Advanced
Ultra Low NOx (ULN)
combustion system

13-stage axial compressor
With four rows of variable vanes
offering
higher part load efficiency

Cooled rotor cooling air
for active clearance
control

A cooled, single tie-bolt rotor
w/ Hirth serrations

Hydraulic clearance
optimization (HCO) active
clearance control

SGT6-5000F

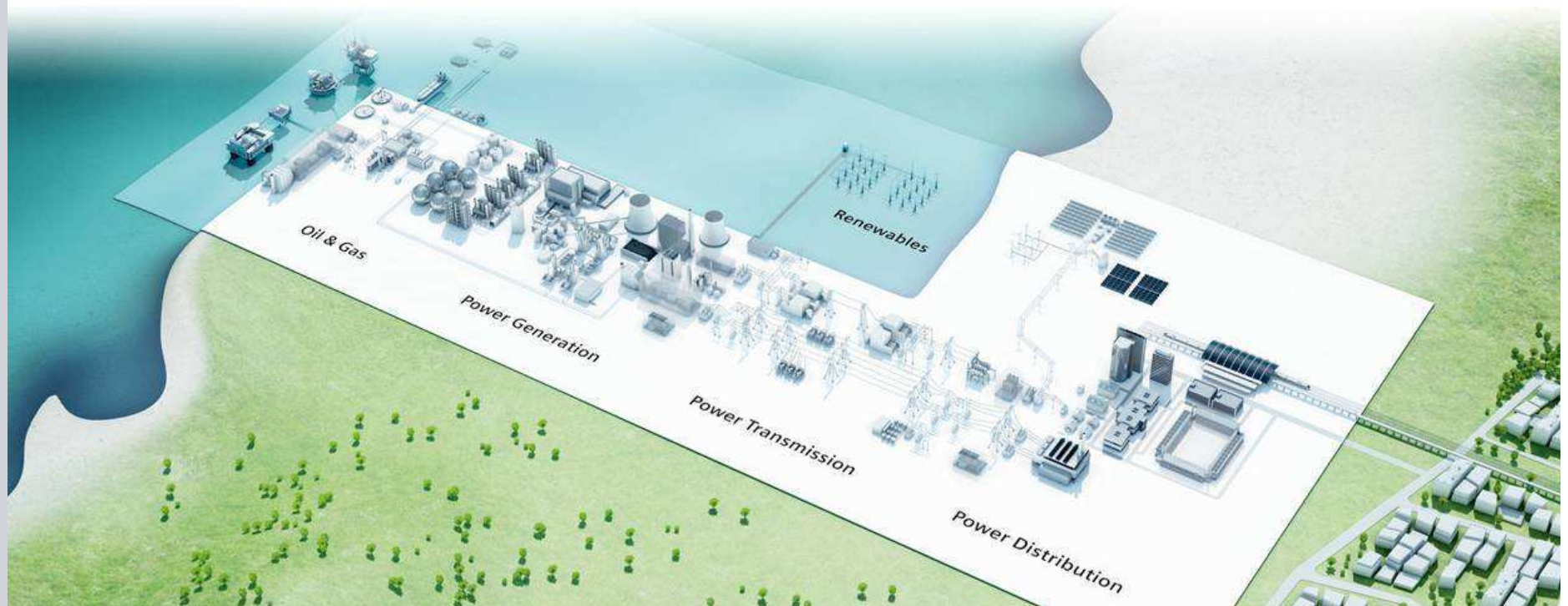
An field proven power house
rated at 208+ MW, 38.5% Efficiency
able to provide up to 150 MW in 10 minutes
and load follow at up to 30 MW/min

SGT6-8000H

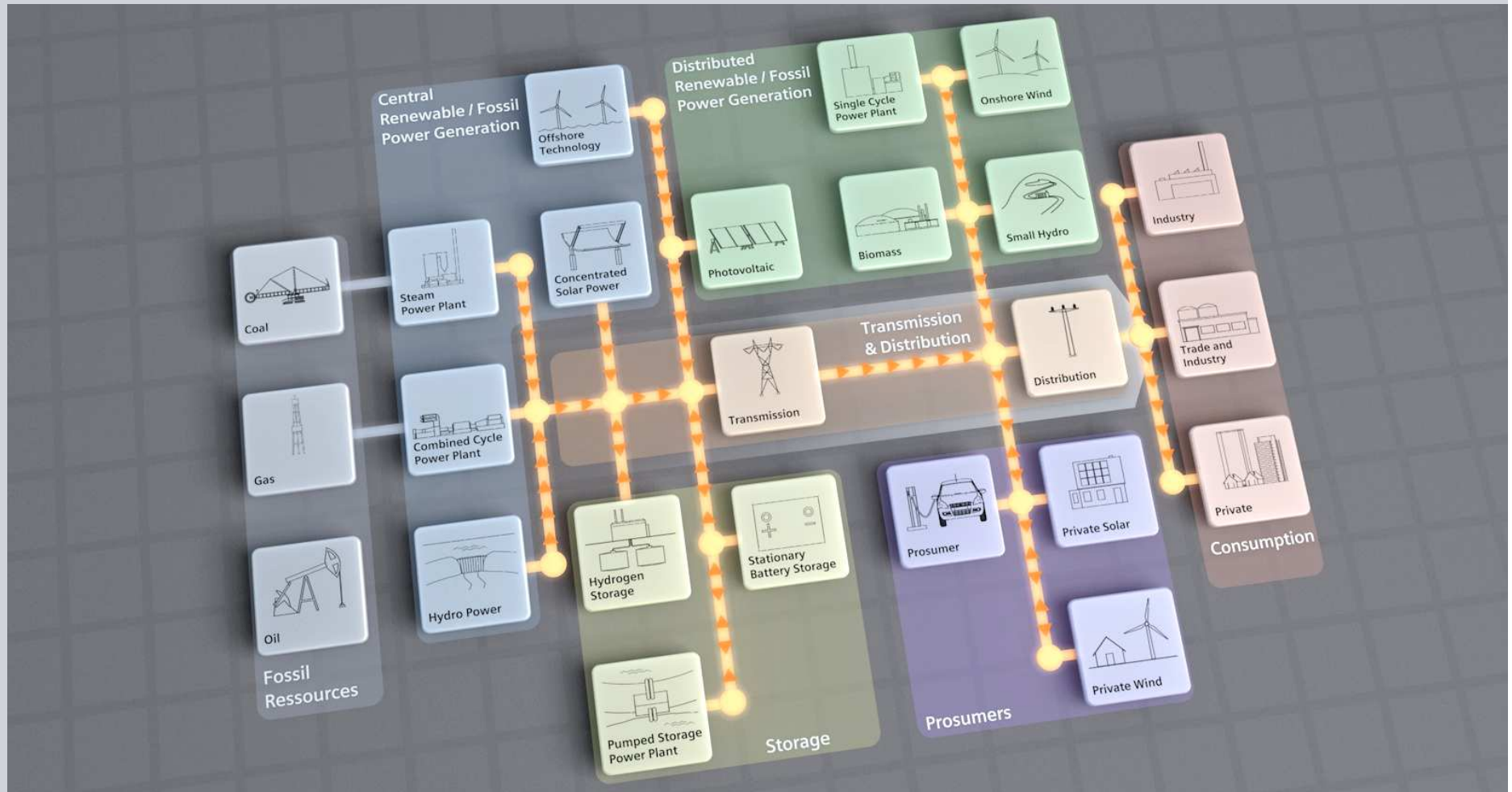
Adding ultra high efficiency to flexibility
rated at 274 MW, 40% Efficiency
able to provide 150 MW in < 10 min
and load follow at up to 30 MW/min

Traditional System View

For decades, we have been successfully working on making energy systems more reliable, intelligent, and eco-friendly.



System Transformation – A new paradigm



THANK YOU!

