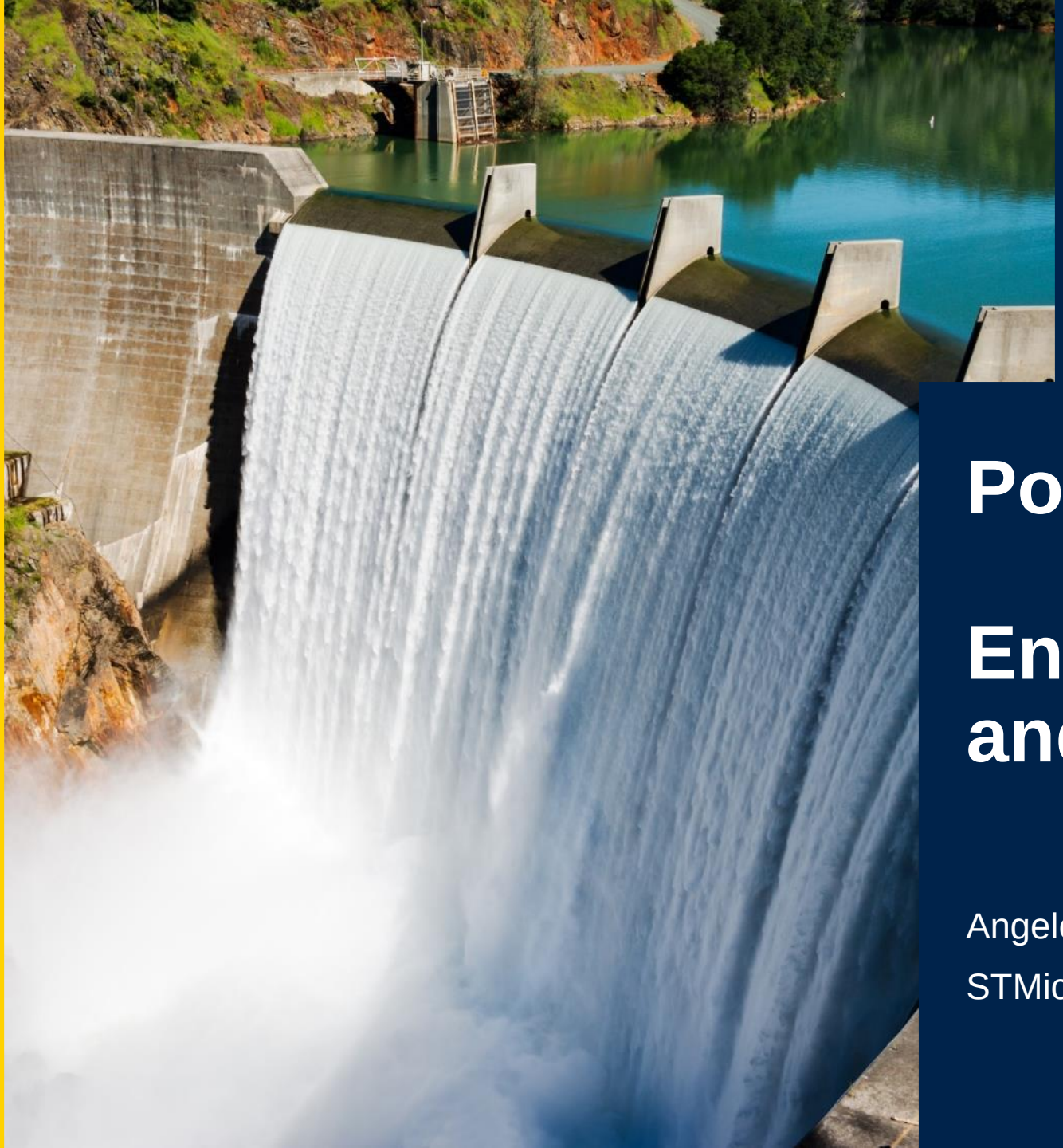

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Power electronics

Enabling sustainability and the green transition

Angelo Rao

STMicroelectronics

Energy transition

Resources are a common asset...

Reduce greenhouse gas emission

- **Transport**: automotive, space & aeronautics
- **Industry**: pumps, motors, air-conditioning, multimodal energy approach
- **Digitalization**: massive data and « real time » calculation, data server, IA, …

➔ « Fossil » energy to be massively reduced

Optimize all usage

- **Electrical power is also scarce**
- From production to…
- Recycling & upcycling

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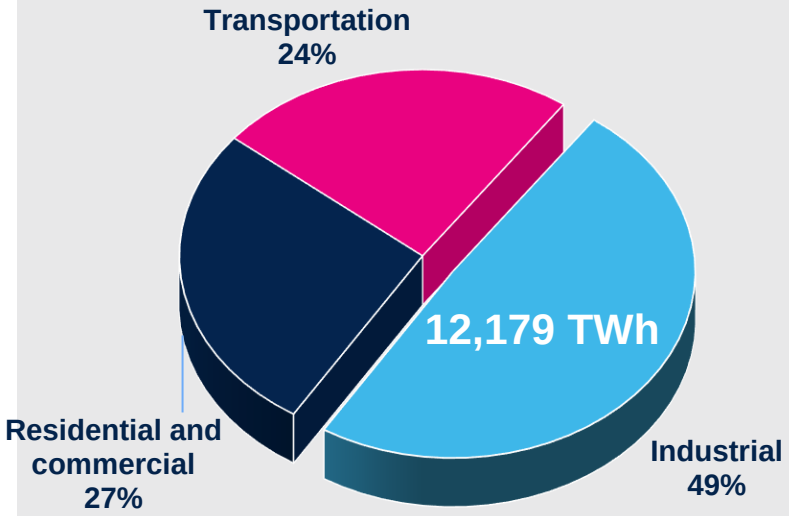
The impact of global energy consumption

Electricity consumption by sector



24,856 TWh: total worldwide electricity consumption (2021)

1% efficiency improvement

in **industrial** electricity

consumption

=

121.79 TWh electricity

saved

By reducing our energy consumption, we can reduce our carbon footprint

~18 standard nuclear plants

66.08 MMBOe

13.85 M tce

3.7 billion

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Can electronics drive sustainability?

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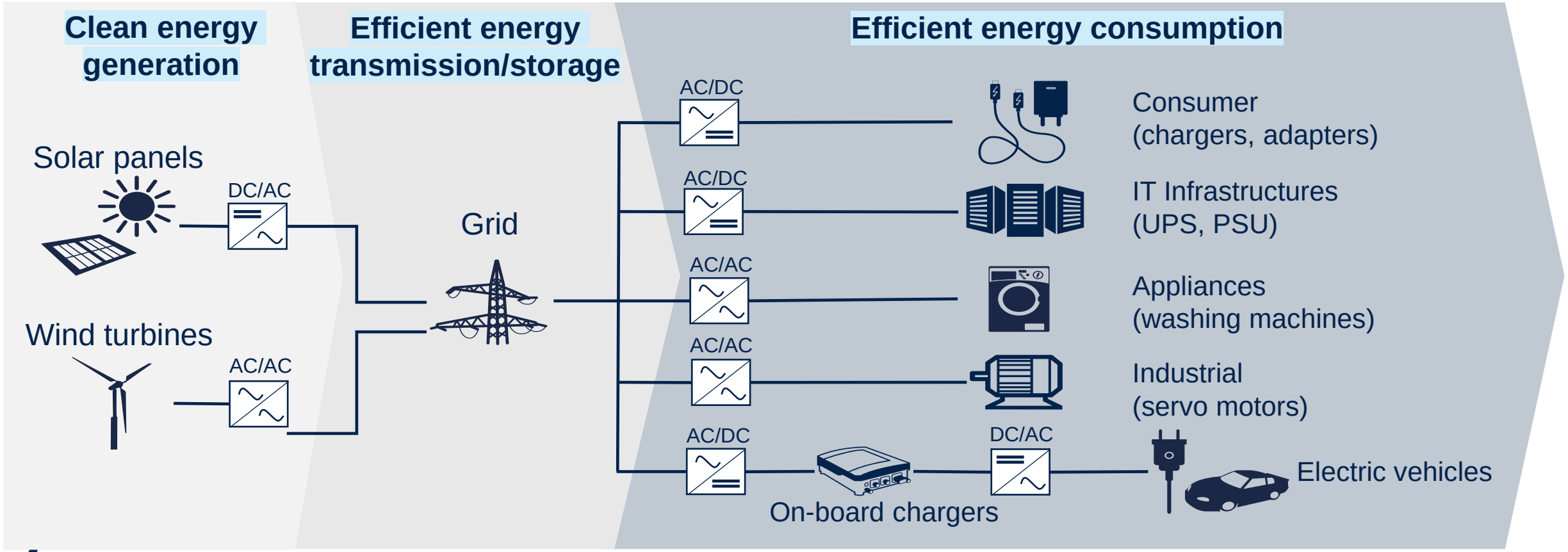
Electricity: the future’s key energy carrier

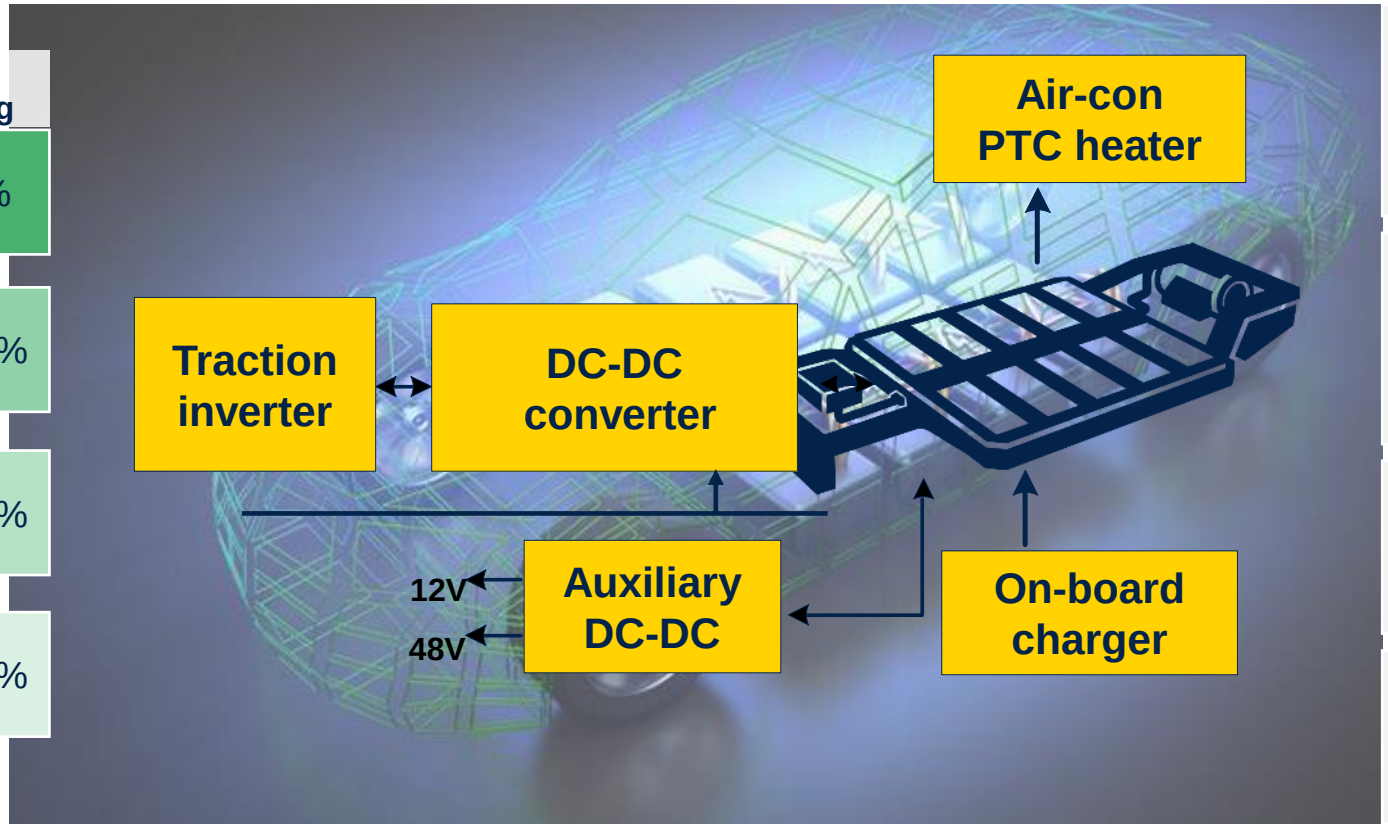
The critical role of power semiconductors in conversion, control, and processing



Contribution of electric vehicles to CO_2 reduction

Road transportation accounts for about 15% of CO_2 emissions globally

Vehicle type	CO_2 saving
Full electric	100%
Plug-in hybrid	50-75%
Full hybrid	20-30%
48 V mild hybrid	15-20%



On-board chargers
SiC, GaN, & Si power MOSFETs, IGBT
Power modules
Rectifiers, fast diodes
Galvanic isolated drivers

DC-DC converter
SiC, GaN, & Si power MOSFETs, IGBT
Power modul
MCU for power conversion
Galvanic isolated drivers

Traction inverter
SiC MOSFET and IGBT
Power modules
Rectifiers, galvanic isolated drivers

48 V system
Smart half-bridges
48 V high-side drivers
Silicon power MOSFETs

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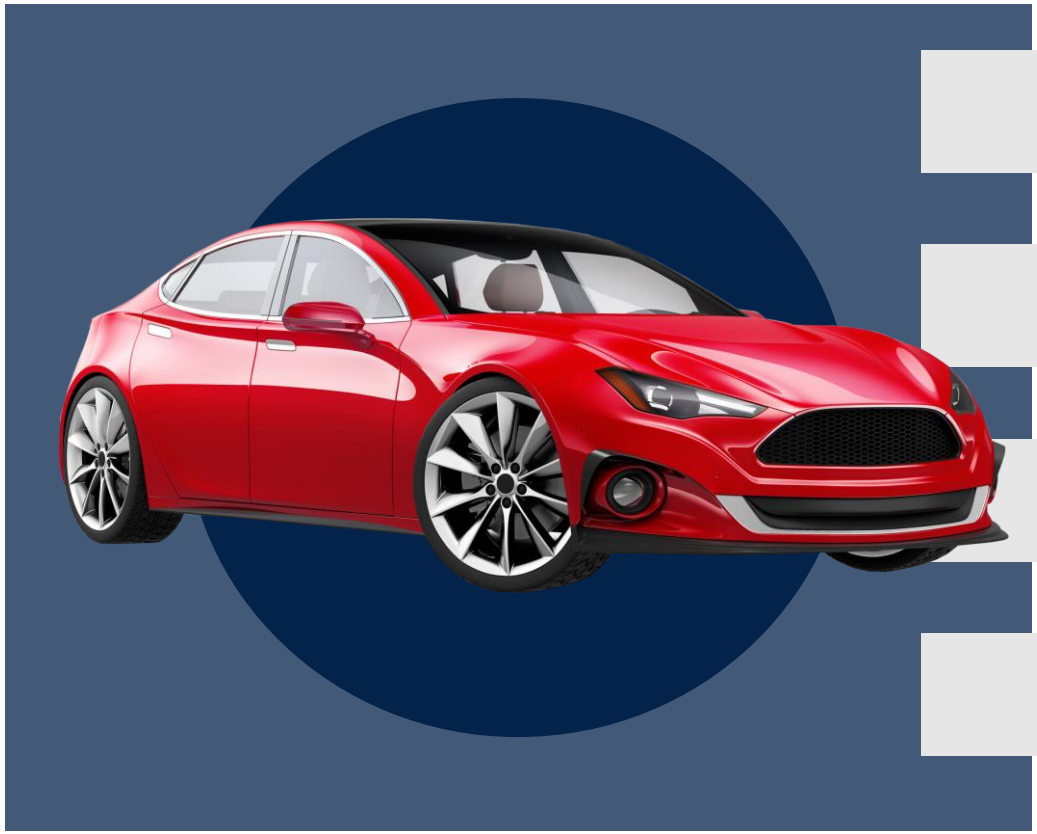
Source: IEA

Where is STMicroelectronics in a EV car

More than 3100 electronic components by ST



Comfort
More than **1000**

- Seat adjustment
- sunroof
- lifting tailgate system

Safety
More than **1000**

- Air-bag & ABS
- BodyGuard collision ADAS

Audio/navigation
More than **500**

- Telematics and Navigation
- Infotainment
- Digital Cluster

Electrification
More than **600**

- Charging
- Traction
- Battery management system

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Home & building energy savings

Residential & commercial lighting, HVAC, and appliances use >50% of total electricity consumption

>40% Energy Saving	**Washing machine**	From Class D to Class A++
>30% Energy Saving	**Air conditioning**	From analog to digital From AC to BLDC control
>70% Energy Saving	**Digital consumer power supply**	Efficiency > 98% in run mode Stand-by power < 1mW
>80% Energy Saving	**Electronic lighting**	From incandescent bulbs to LED lighting

Power management
Power Factor Corrector
Power Converter ICs
LED Drivers

Power switches & drivers
Power MOSFETs, IGBT
Power Modules and IPM
Driver ICs

Sensors & control unit
Microcontrollers
Motion and environmental sensors

Motor control
Microcontrollers
Application Specific Standard Products
System in Package

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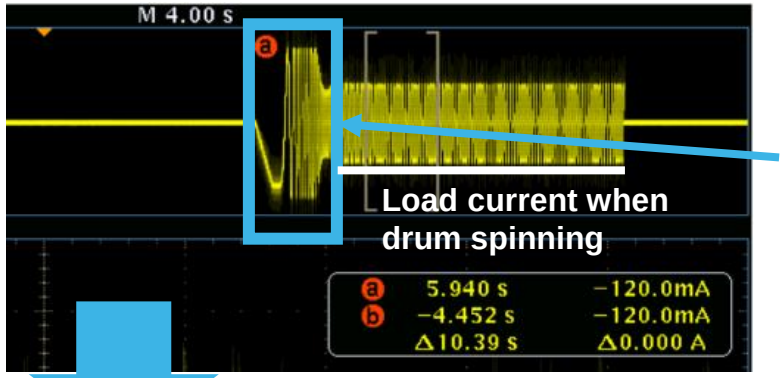
Source: IEA,EPA

Adding intelligence to save energy & resources

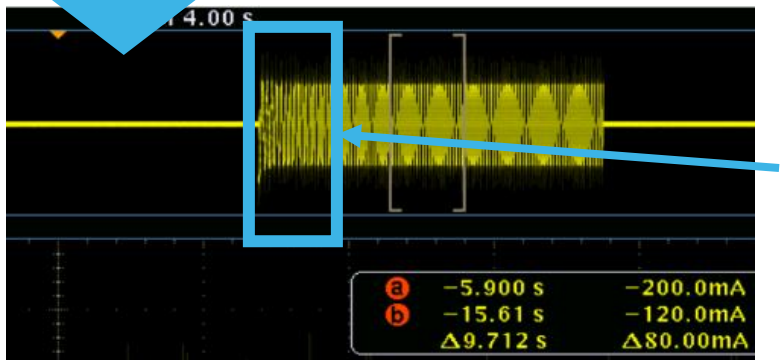
Combination of **Edge AI clothes weighing** and **advanced Motor control algorithms** reduce the amount of water and detergent used and significantly lowers start up current

Energy saving per washing cycle ~15-40%

Standard (open loop) sensorless startup



High peak current



No high peak current
Shorter start-up

Zero Speed Full Torque (ZeST) sensorless start-up

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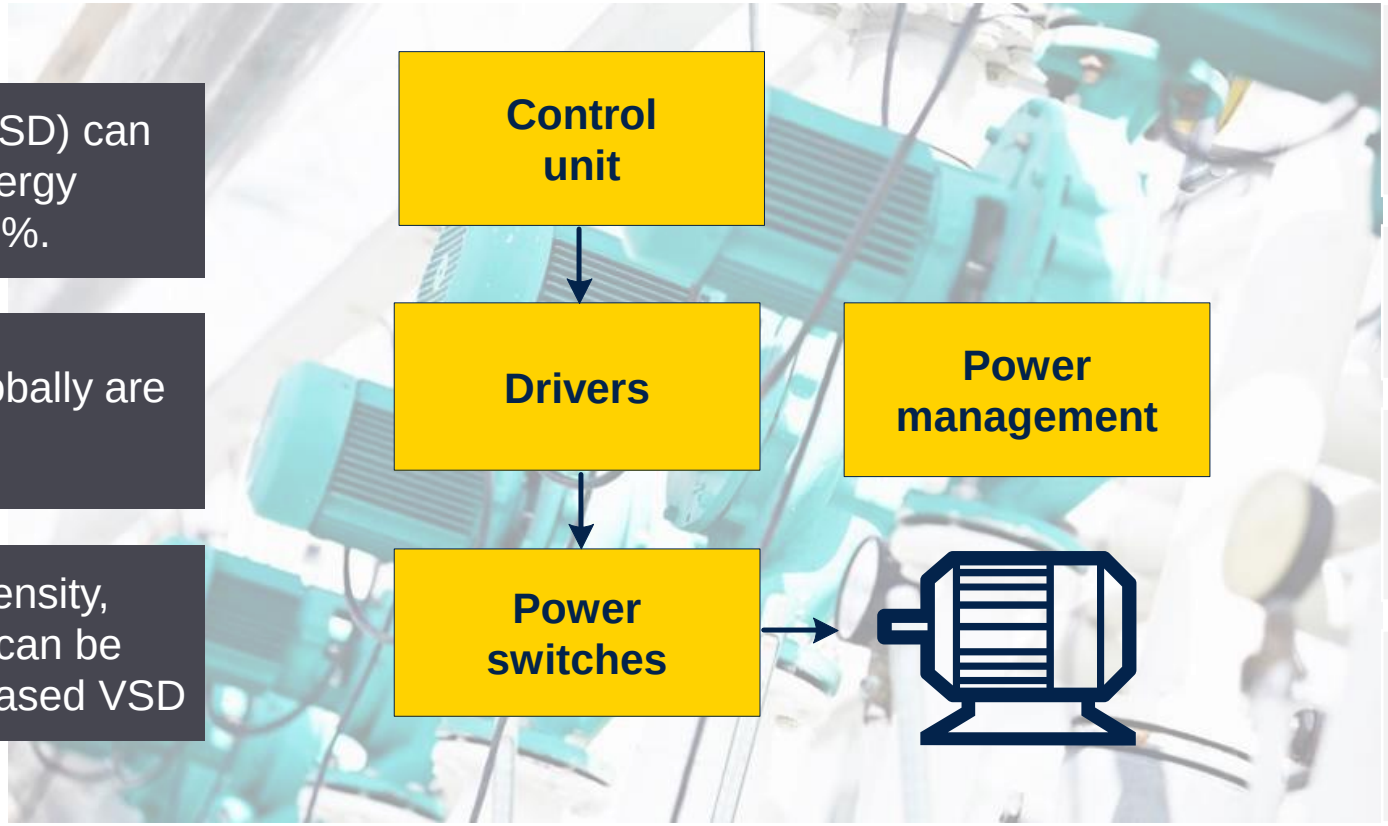
Potential energy savings with electric motors

Nearly 70 percent of all industrial electrical energy is used to power electric motors

Variable speed drives (VSD) can reduce electric motor energy consumption by up to 50%.

Only ~12% of motors globally are equipped with VSD

Efficiency, size, power density, and overall system cost can be improved using WBG*-based VSD



Power switches
WBG MOSFETs
IGBT, IPM, Power Modules and Silicon Power MOSFETs

Drivers
Gate Driver ICs

Control unit
Microcontrollers
Application Specific Standard Products
System in Package

Power management
Power converter ICs
Rectifiers, Thyristors
Silicon Power MOSFETs and IGBT

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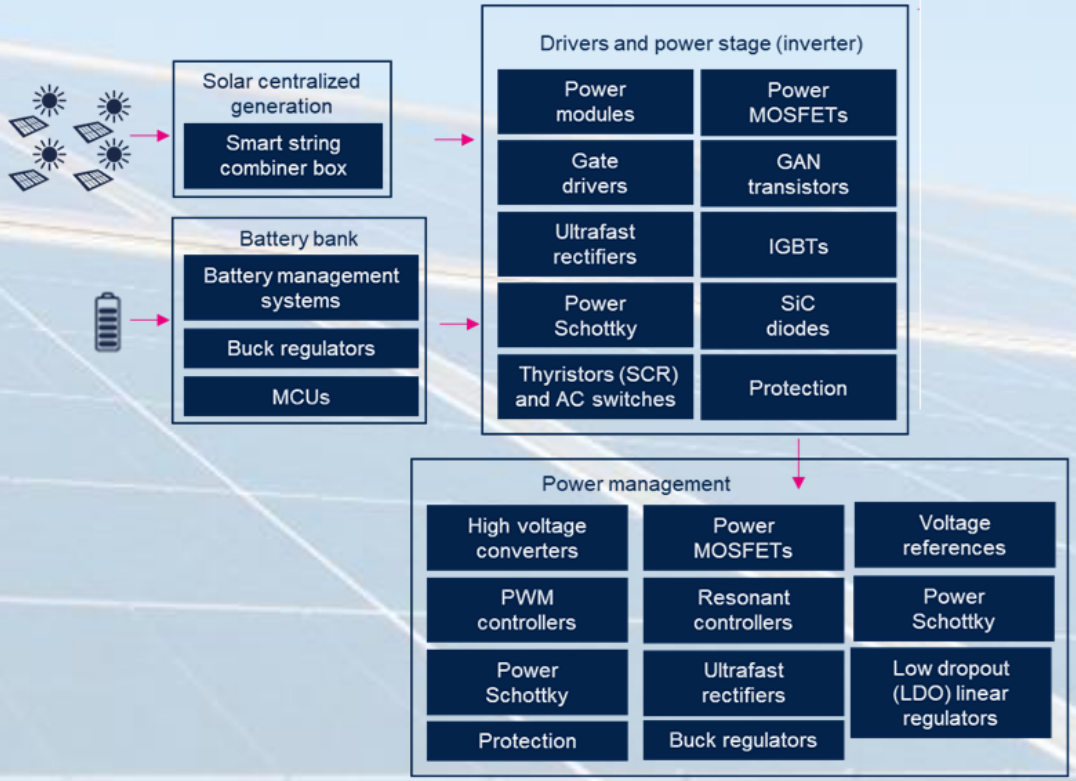
*WBG = Wide Bandgap Semiconductors such as Silicon Carbide and Gallium Nitride

Source: ABB, ARPA

Solar power generation

Solar panels can generate, store, & share electricity thanks to semiconductors

3.6% solar PV power In 2021	**Of global electricity generation**
22% growth vs 2021	**In global solar PV power generation**
38% from China	**PV power generation growth**
7x PV production	**Increase required by 2030 vs 2021 for Net Zero Scenario**



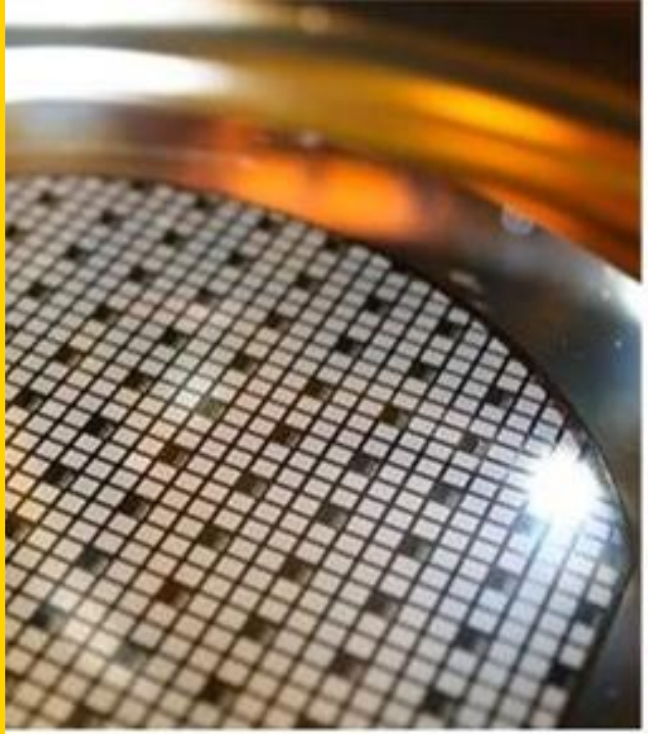
Key components

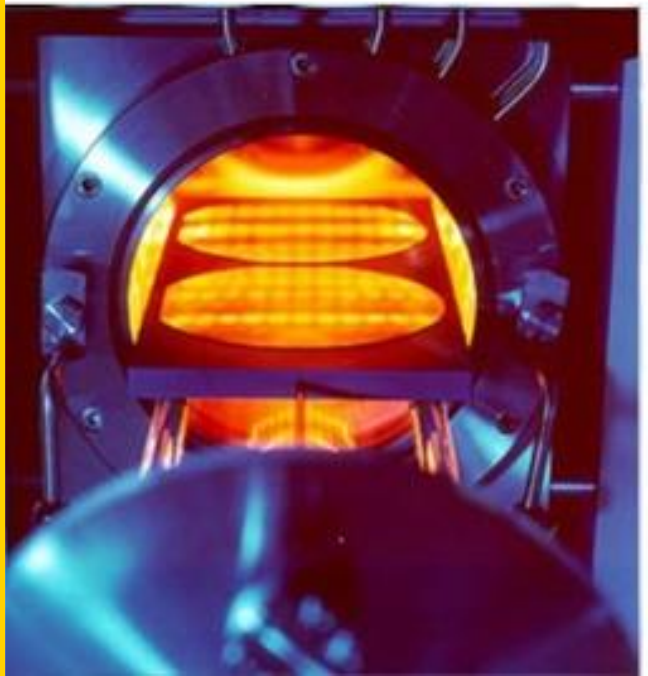
Inverter
SiC, GaN, & Si power MOSFETs, IGBT
Power modules
Rectifiers, fast diodes
Galvanic isolated drivers

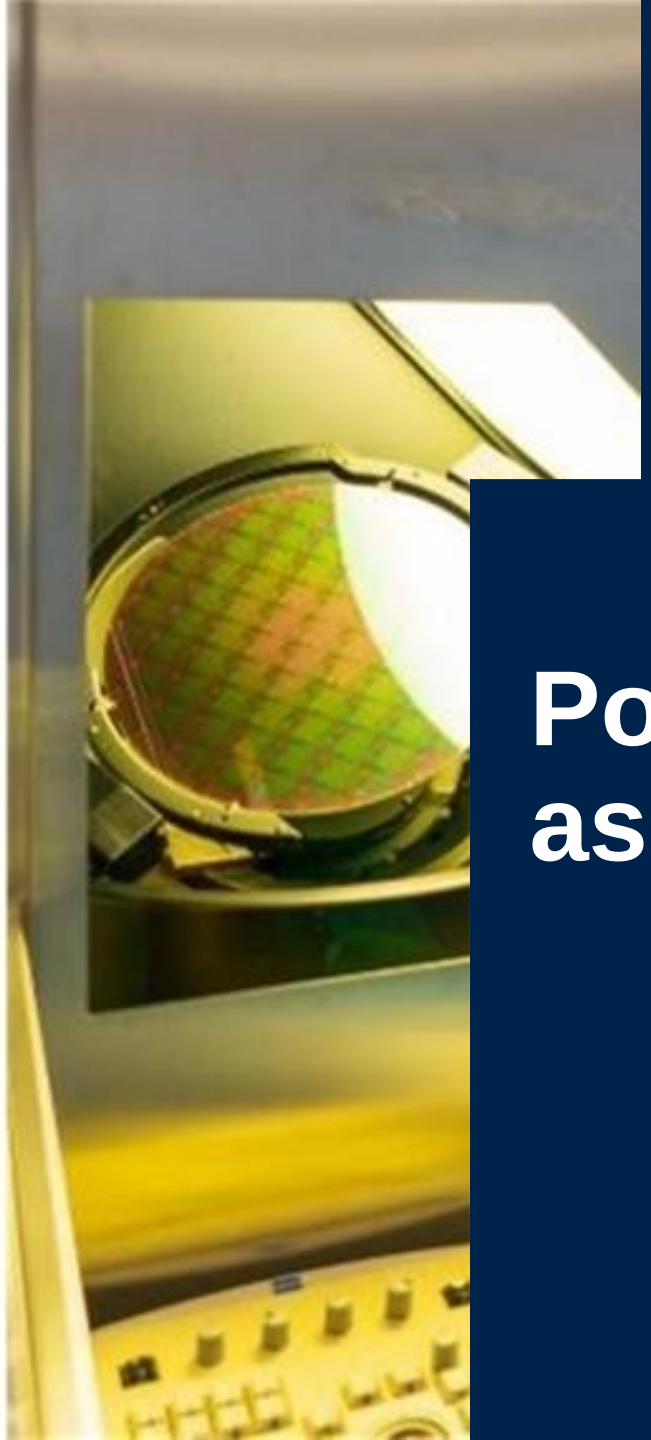
Power management
SiC, GaN, & Si power MOSFETs
Power modules
Rectifiers
PWM controllers
Galvanic isolated drivers

Battery management
Battery management ICs
Microcontrollers
Regulators

Source: IEA







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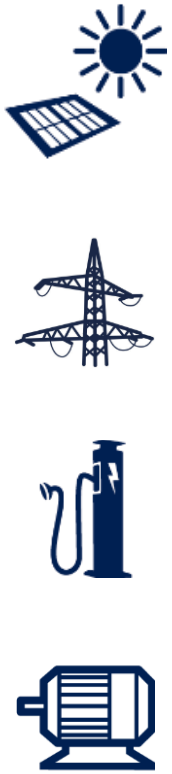
Power semiconductors as key enablers

ST strategy in power electronics



...address

Green energy generation

Energy distribution

Energy storage

Electrification

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...with ST innovation

Efficiency / Standby
- Optimization of existing silicon
- WBG technologies (SiC & GaN)
- Smart controllers

Power Density & integration
- Embedded galvanic isolation
- System in package (SiP)
- Innovative packages

Flexibility & advanced features
- Digital power controller

Efficient solutions enabled by highly efficient semiconductors

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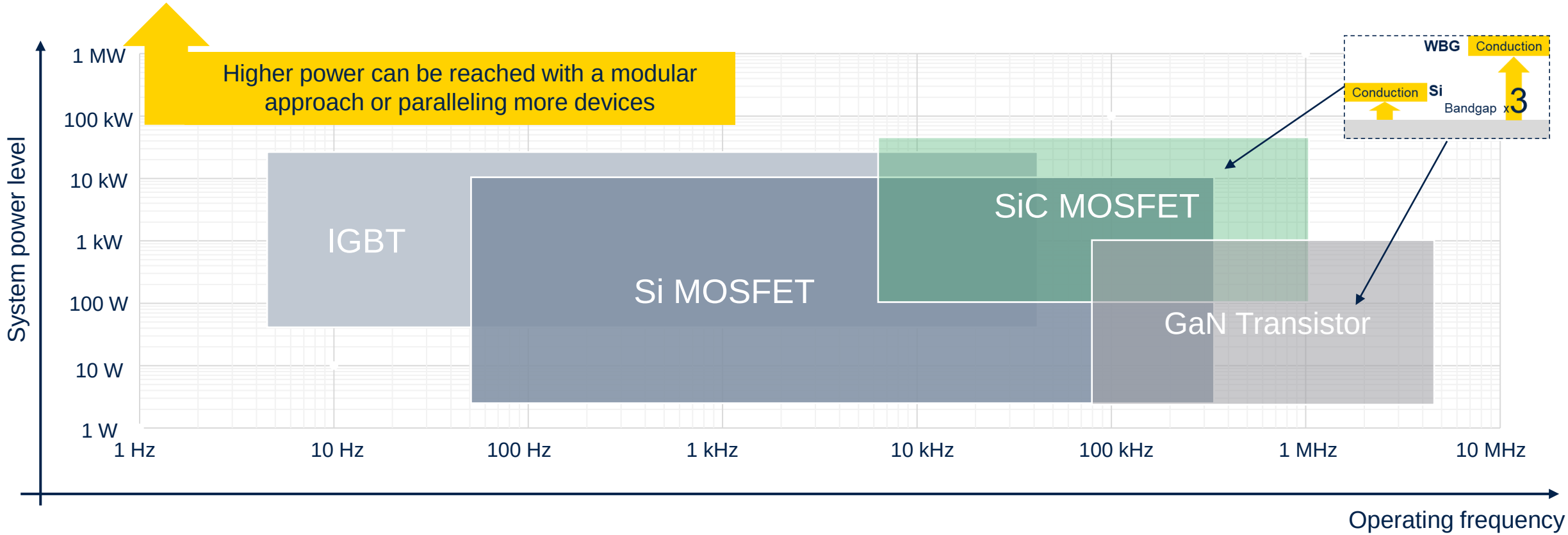
Si, SiC, and GaN mapping

Silicon and wide bandgap materials are complementary



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Advanced packaging discrete and module solution

Leadless package

Permeation of leadless package enablers for miniaturization

PowerFLAT

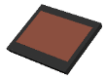
TO-LL

Top-side cooling SMD package

SMD packages that allow direct connection to heatsink

LFPAK 12x12 TSC

HU3PAK



DirectGaN DSC PEP

Modular package

Multi-purpose configurations, high power, top-side cooling

ACEPACK SMIT

Leaded package

Standard packages that benefit from economy of scale

SOT223-2L

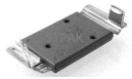
DPAK

TO247-4L

H2PAK-7L

Multi-sintering package

High reliability, high power density, sintering on heat sink



STPAK

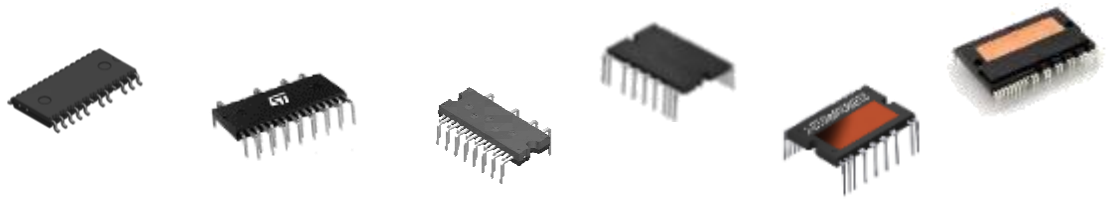
Bare Dice

For high-temperature or customer in-house assemblies

Tested cut/uncut wafer

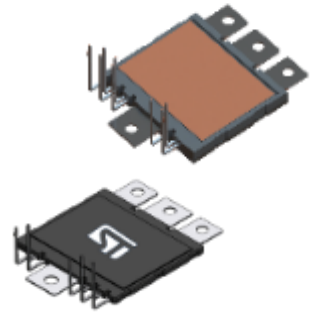
Tested dice in T&R

SLLIMM Intelligent Power Module



ACEPACK Power Module

(*) R&D stage



Not complete list – just overview

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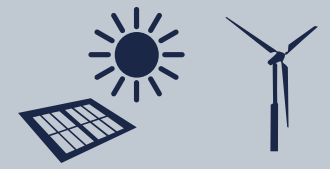
Benefits of SiC technology

Key advantages of SiC for automotive	and related infrastructure
 Traction inverter, on-board charger & DC-DC	 Charging station
Longer driving range	> 600 km with SiC
Faster charging	SiC charging station handles 2x the energy
Car weight reduction	1% saving in the overall weight and space of an EV

Key advantages of SiC for industrial	
 Factory automation  Power supply for servers  Renewable energy	
Increased power efficiency	50% lower losses and with 5x frequency
Reduced total cost of ownership	Reduction of 20%
Smaller, more compact machines	Size/weight by 70%/80% with an average 50% reduction

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Benefits of GaN technology

Fast charging tablets and notebooks

- 4x smaller
- 3x lighter

Power supplies for telecom and data centers/AI servers

- ↑50% power density
- ↓20% power losses

Solar ESS (energy storage system)

- 2x smaller
- 3x lighter

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Silicon technology continues its march

	PowerMESH	SuperMESH	MDmesh II	MDmesh M2	MDmesh M5	MDmesh M6	MDmesh M9
High Voltage Power MOSFET	1995	2002	2005	2009	2013	2016	Today
improvement		-35%	-77%	-85%	-87%	-90%	-95%

	Platinum implant	Electron irradiation	Trench Filed Stop	Fine cell pitch	Multiple deep Field Stop
IGBT	1995	2004	2012	2019	Today
improvement		-20%	-40%	-55%	-65%

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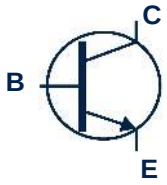
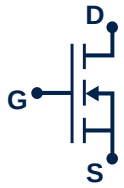
Power Transistor
Overview by technologies and applications

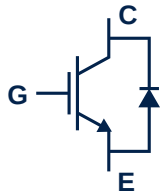
Silicon-based transistors



Power Bipolar



MOSFET

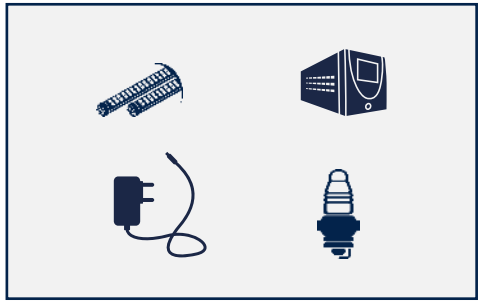


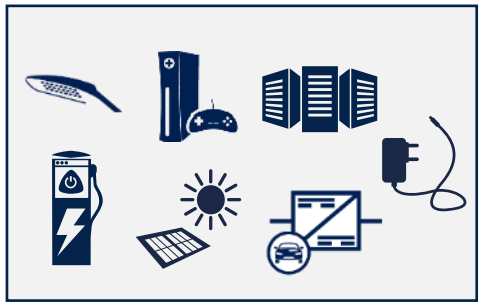
IGBT

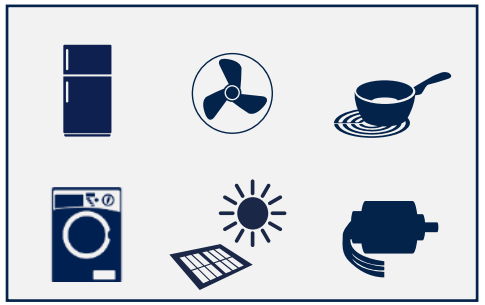
The bipolar Junction Transistor (BJT) is a 3-terminal, current-controlled electronic device that amplifies the current injected into the base B. In a bipolar junction transistor, electric current is conducted by both free electrons and holes.

MOSFET stands for metal-oxide-semiconductor field-effect transistor. The silicon-based MOSFET is a vertical, 3-terminal device with gate, drain and source terminals. Current conduction between drain and source is controlled by a voltage applied to the gate terminal G.

Insulated gate bipolar transistor is something of a cross between a conventional BJT and a vertical MOSFET. It has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a conventional MOSFET.

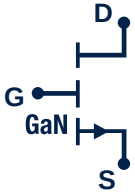






WBG-based transistors

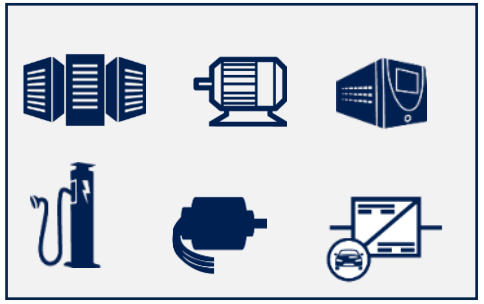
SiC MOSFET



Power GaN Transistor

SiC MOSFET is a wide bandgap material offering excellent static, dynamic and thermal performances. SiC-based MOSFETs are more tolerant to high temperatures and can be operated at higher voltages and higher switching frequencies.

Power GaN Transistors are High Electron Mobility lateral Transistors (HEMT) based on gallium nitride (GaN), a new wide bandgap material. They deliver major gains in terms of efficiency and power density involving high frequency-operation and low on-state resistance.



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ST product portfolio enabling strategic trends

STPOWER

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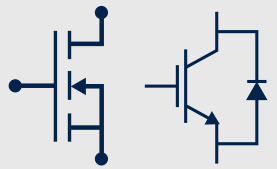
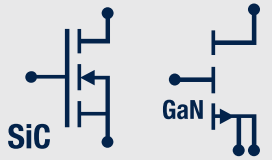
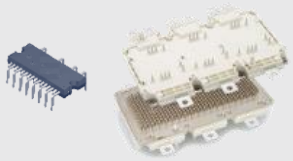
Silicon devices		High-voltage MOSFETs IGBTs, Power RF (LDMOS, DMOS)
Wide-bandgap (WBG) devices		SiC MOSFETs Power & RF GaN
Modules		Intelligent Power Modules (IPM) High Power Modules

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