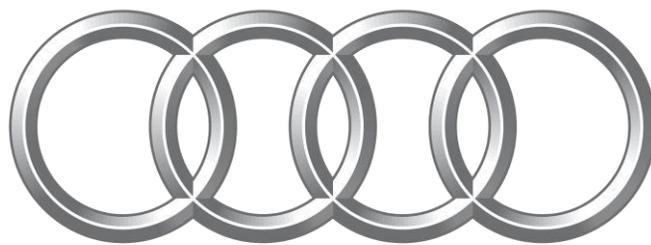


# **Audi Lighting and ADAS**



**Progress through technology  
"Vorsprung durch Technik"**

Published 15 December, 2020



**Audi**



**DrivingVisionNews.com**

Automotive lighting, driver assistance and smart interior

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# Audi Lighting and ADAS

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# Executive Summary



Audi, a wholly-owned subsidiary of the Volkswagen Group, are one of the auto industry's longest-established companies. Headquartered in Ingolstadt, Bavaria, Germany, they specialise in premium cars; they made 1.8 million of them in 2019. Audis are exquisite cars—attractive, sophisticated, and technically advanced. Their success stems from creativity, commitment and enthusiasm. The wishes and emotions of their customers drive Audi's innovation-forward approach to realising the brand's motto of "Vorsprung durch Technik" (Progress through technology). Audi have deliberately positioned themselves as leaders in lighting, and—unusually for an automaker—top executive management is involved in lighting, which is an important focal point in Audi's short-, mid-, and long-term strategic planning.

Chapter is dedicated to the R&D organisation of Audi's lighting team, management of the department, of front and rear lighting development, projects, and creative lighting designs, and the facilities, including the LAZ famous light tunnel, where the magic happens.

Audi's main lighting innovations are described, including digitalisation which allows interaction with surroundings; dynamic turn signals; HD matrix headlighting technology with DMD; OLED rear lamps which look amazing and open the door to V2X communication; welcome and farewell dancing-light displays, the new strategy wherein Audi owners can pay for additional lighting functions to be activated by software even after having purchased their car, and more.

We present interviews with Audi lighting chiefs Wolfgang Huhn and Stephan Berlitz, as well as an interview done at the Audi TechTalk Light event early in December 2020.

A chapter is also dedicated to interior lighting, with the megatrends to support future use cases, and another to feedback of Audi suppliers and partners.

We describe the individual vehicles in Audi's model range, with a detailed scrutiny of front, rear, and interior lighting on each model, with the confirmation of the lighting strategy: No halogen in any new Audi models except A1 in Entry model, e-Tron, the first Audi model with matrix in Entry model and with DMD in option, A5 to A8 and Q7-Q8 use Matrix in Entry model.

and the last chapter covers ADAS developed by Audi, as well

# 1. Volkswagen Group

## 1.1 Volkswagen Group History

- Volkswagen (literally: "People's car") got started in 1937, to manufacture the car designed by Ferdinand Porsche at the behest of Adolf Hitler. 21 million Beetles, as they came to be known, were produced round the world from 1946 to 2003.



- In 1965 VW acquired Auto Union, which subsequently produced the first postwar Audi models.
- In 1986 VW acquired a controlling stake in Spain-based SEAT, making it the first non-German VW marque.
- In 1994 VW acquired control of Czech automaker Škoda.
- In 1998 VW acquired Bentley, Lamborghini, and Bugatti.
- In 2008 VW acquired Scania.
- In 2012 VW acquired Ducati, MAN, and Porsche.
- VW have especially important operations in China with two main joint ventures, FAW-VW and SAIC-VW. China is now the № 1 market of the Volkswagen group.
- VW also entered the India market recently. The VW group now employ more than 4,800 people in the facilities of Škoda auto Volkswagen India, with a capacity of 200,000 vehicles.

### VW Group's 12 brands:



## 1.2 Board Composition



**D.ing. Herbert Diess:** Chairman of the Board of Management



**Oliver Blume**  
Brand Group,  
Sport and Luxury



**Markus Duesmann**  
Brand Group,  
Premium



**Gunnar Kilian**  
HR Brand Group  
Trucks and bus



**H. Dorothea Werner**  
Integrity and  
legal affairs



**Frank Witter**  
Finance and IT

### 1.3 Volkswagen Group Main figures

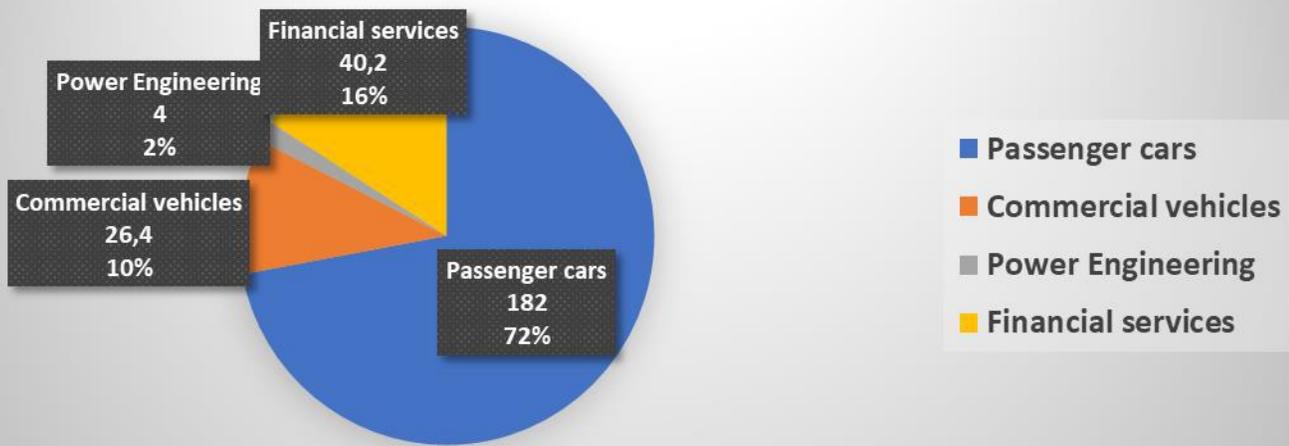
- 11.83 million vehicles sold in 2019 (including JVs in China); global № 1; 2019 market share 12.9% (12.2% in 2018)
- Sales in 2019: €252.6bn, up 7% vs 2018
- 671,200 employees at end 2019, up 1% vs 2018
- 125 plants in 20 countries in Europe and 11 countries in Americas, Asia, and Africa
- Profit after tax 2019: €14.0bn, up 14.7% compared to 2018
- R&D expenditures 2019: €14.3bn, up 4.9% vs 2018; 6.7% of sales
- In the first three quarters of 2020, due to the pandemic, sales decreased by 18.7%; revenues by 26.7%, and earnings after tax by 85% but still positive at €1.7bn. Nevertheless, Q3 2020 was close to 2019 with a slight decrease of 1.1% in units and 3.4% in €. For this Q3 2020, the level of earnings after tax was €2.75bn, good in these conditions, with however RD investments decreased by 4.7% compared to 2019

#### KEY FIGURES BY BRAND AND BUSINESS FIELD

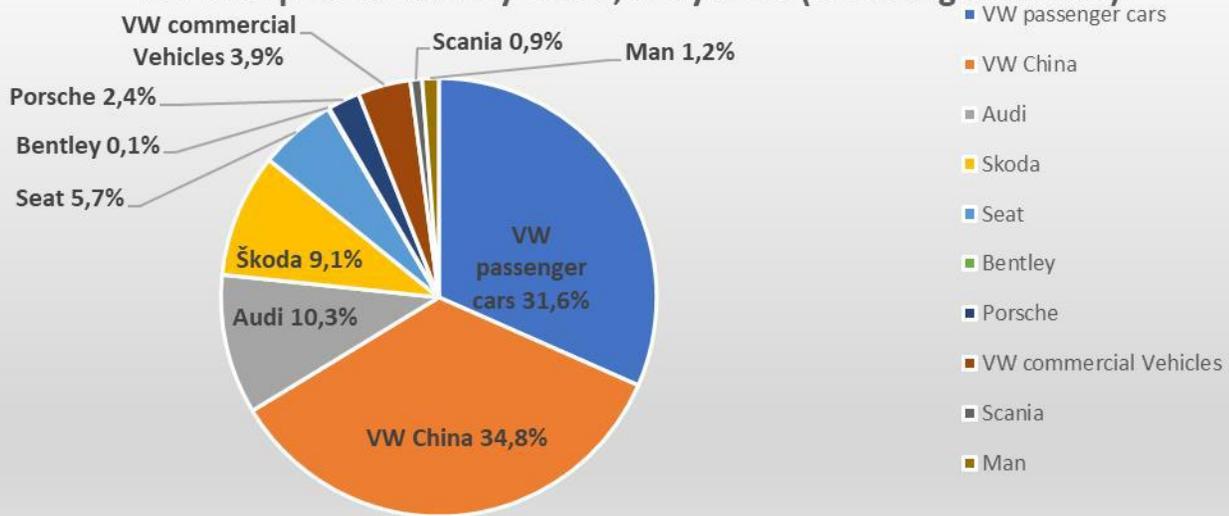
Thousand vehicles/€ million	VEHICLE SALES		SALES REVENUE		OPERATING RESULT	
	2019	2018	2019	2018	2019	2018
Volkswagen Passenger Cars	3,677	3,715	88,407	84,585	3,785	3,239
Audi <sup>1</sup>	1,200	1,467	55,680	59,248	4,509	4,705
ŠKODA <sup>1</sup>	1,062	957	19,806	17,293	1,660	1,377
SEAT	667	608	11,496	10,202	445	254
Bentley	12	10	2,092	1,548	65	-288
Porsche Automotive <sup>2</sup>	277	253	26,060	23,668	4,210	4,110
Volkswagen Commercial Vehicles	456	469	11,473	11,875	510	780
Scania Vehicles and Services <sup>3</sup>	101	97	13,934	12,981	1,506	1,207
MAN Commercial Vehicles	143	137	12,663	12,104	402	332
Power Engineering	-	-	3,997	3,608	159	193
VW China <sup>4</sup>	4,048	4,101	-	-	-	-
Other <sup>5</sup>	-685	-912	-30,931	-34,029	-917	-1,418
Volkswagen Financial Services	-	-	37,957	32,764	2,960	2,612
<b>Volkswagen Group before special items</b>	-	-	-	-	<b>19,296</b>	<b>17,104</b>
Special items	-	-	-	-	-2,336	-3,184
<b>Volkswagen Group</b>	<b>10,956</b>	<b>10,900</b>	<b>252,632</b>	<b>235,849</b>	<b>16,960</b>	<b>13,920</b>
Automotive Division <sup>6</sup>	10,956	10,900	212,473	201,067	13,748	11,127
of which: Passenger Cars Business Area <sup>7</sup>	10,713	10,666	182,031	172,678	12,188	10,000
Commercial Vehicles Business Area <sup>7</sup>	243	234	26,444	24,781	1,653	1,191
Power Engineering Business Area	-	-	3,997	3,608	-93	-64
Financial Services Division	-	-	40,160	34,782	3,212	2,793

Source: annual report 2019

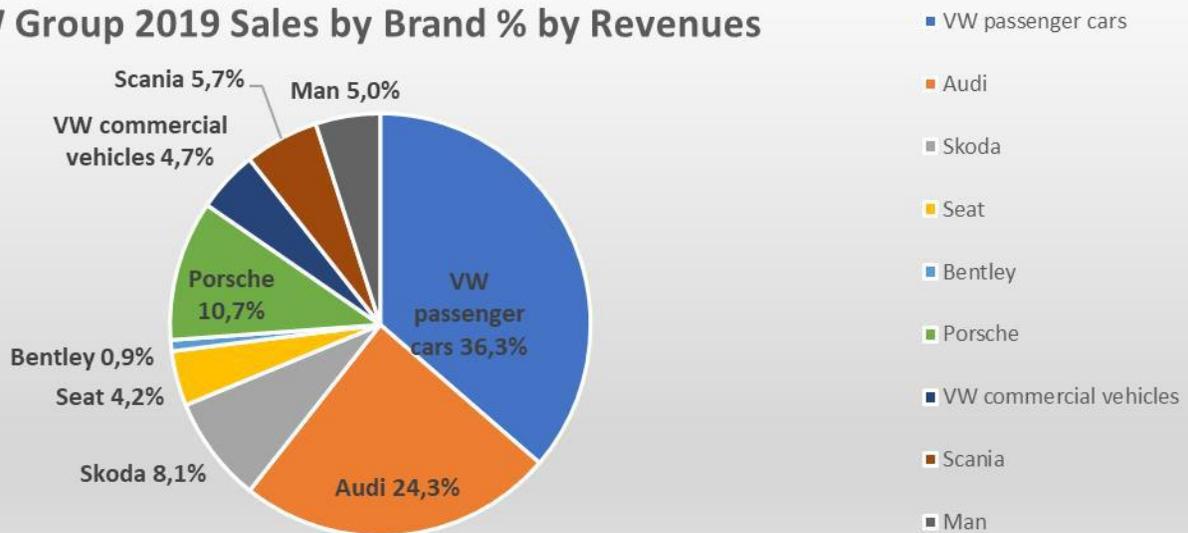
## Volkswagen Group 2019 Sales by type



## VW Group 2019 Sales by Brand, % by units (Excluding China JVs)



## VW Group 2019 Sales by Brand % by Revenues

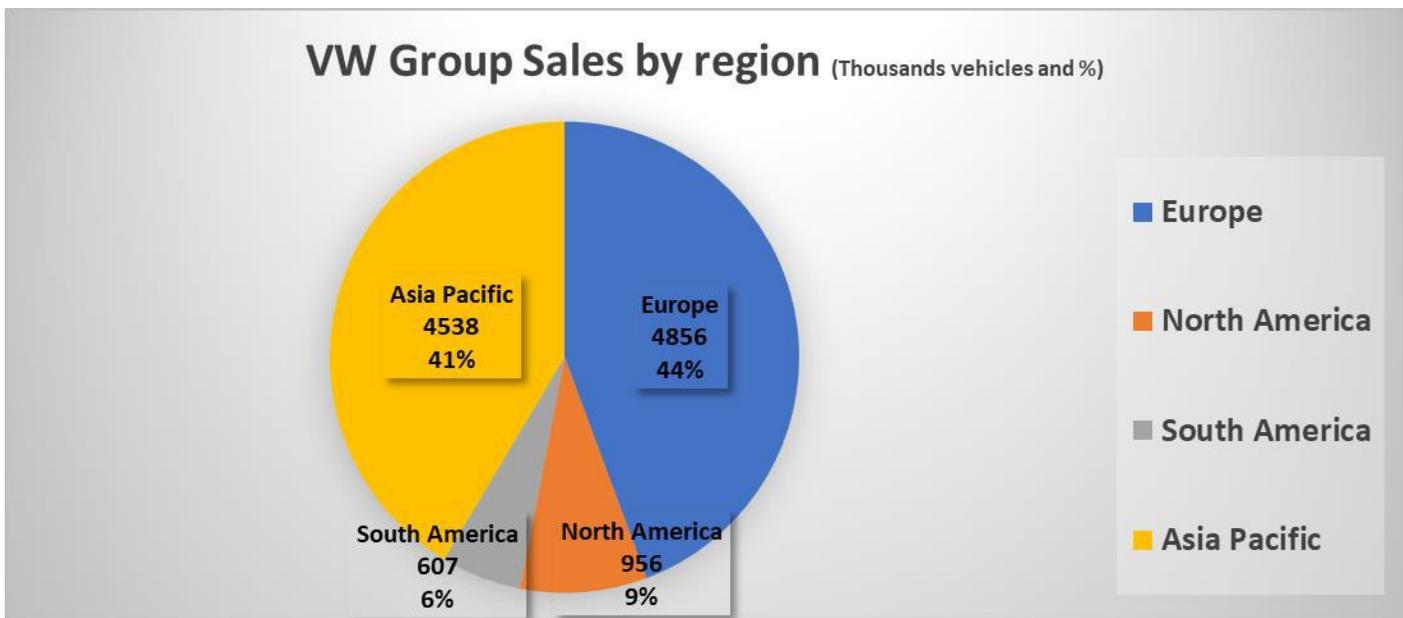


KEY FIGURES BY MARKET

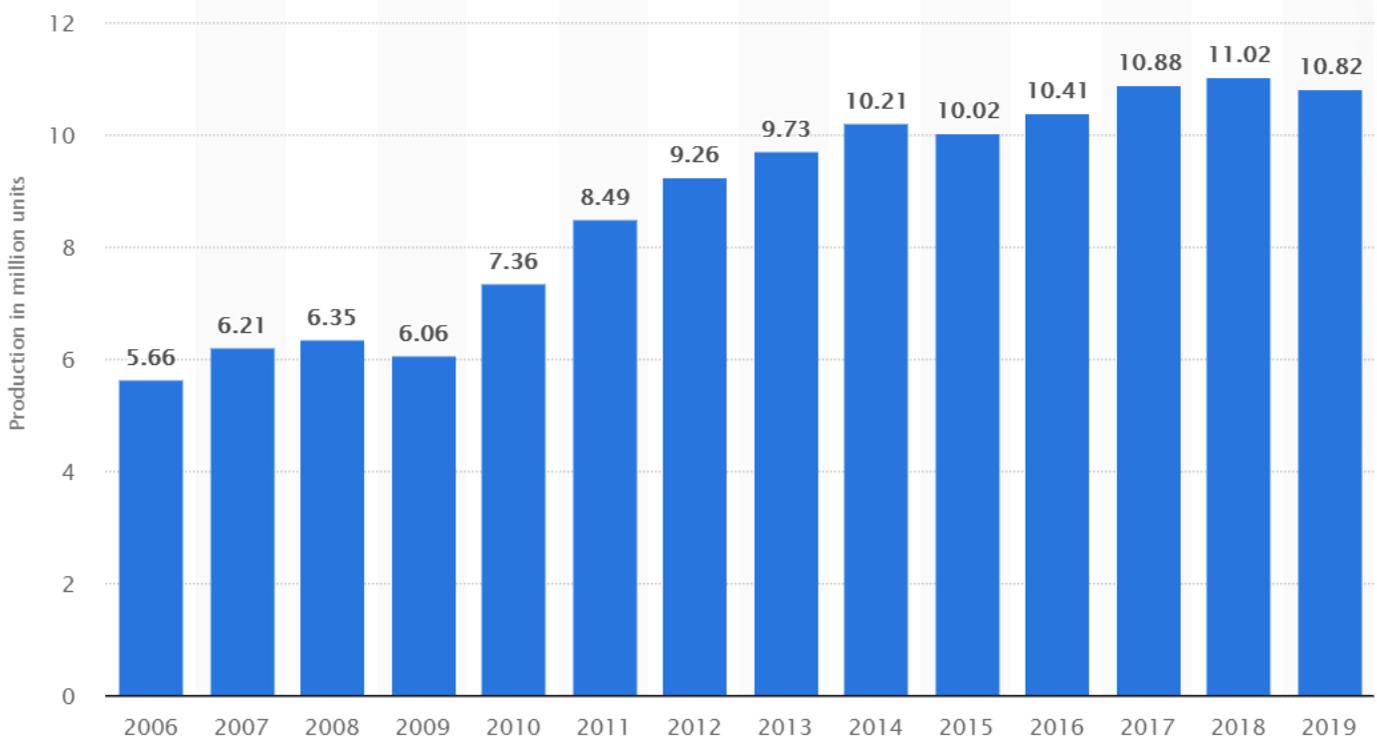
Thousand vehicles/€ million	VEHICLE SALES		SALES REVENUE	
	2019	2018	2019	2018
Europe/Other markets	4,856	4,739	153,999	143,089
North America	956	925	43,351	37,656
South America	607	596	11,297	10,405
Asia-Pacific <sup>1</sup>	4,538	4,640	43,974	43,166
Hedges on sales revenue	-	-	11	1,535
<b>Volkswagen Group<sup>1</sup></b>	<b>10,956</b>	<b>10,900</b>	<b>252,632</b>	<b>235,849</b>

1 The sales revenue of the joint venture companies in China is not included in the figures for the Group and the Asia-Pacific market.

Source: annual report 2019



VW Group Sales, 2006 to 2019 (source: statista.com)



### Vehicle production locations



### Strategy and Main Targets of Volkswagen Group (per 2019 financial report)

Volkswagen Group in 2015-2016 faced giant consequences all over the world for what was deemed to be deliberately deceptive diesel emissions noncompliance, particularly in America where penalties payable to the government, users, and dealers exceeded \$20bn. The company subsequently put new attitudes and values at the centre of their strategy. In 2019, the group updated the strategy for 2025 under the slogan "TOGETHER 2025+" with a new vision "Shaping mobility for generations to come." The ambition is to devise and commercialise answers to the challenges of today and tomorrow, with the goal to make mobility sustainable for future generations with electric drive, digital networking and autonomous driving to make the automobile



clean, quiet, intelligent, and safe.

Five modules underpin this vision and strategy, symbolised by this pictogram:



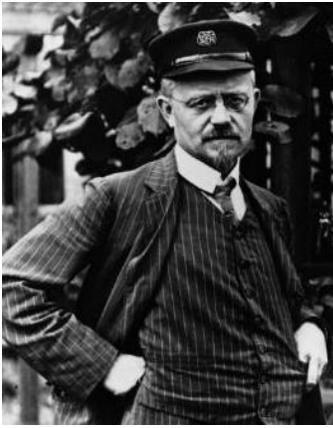
- Best governance: focused, lean, trustworthy
- Best performance: efficient, profitable, sustainable (target 2025: return on sales at 7-8% and return on investment at 15%)
- Best brand equity: sharpened brands, full potential
- Software-enabled car company: On the way to becoming a tech company; target to make software the new core competence of VW group, with a cross-brand software platform for vehicles and the Volkswagen Automotive Cloud fully implemented in 2025.
- Excellent Leadership: versatile, scrupulous, strong; target to have the right talents in the right positions at the right time.



## 2. Audi Brand

### 2.1 History

August Horch created the company in 1899 and the first Horch automobile was produced 2 years later in 1901 in Zwickau. The Audi brand name comes from Latin translation of the founder's name: "Horch" means "listen" in German, which is "audi" in Latin (as in "audio" and "audible"). The four rings of the Audi logo represent the four car companies that banded together to create Audi's predecessor company, Auto Union.



*August Horch*



*August Horch and his wife in front seat*

- 1901: First Horch car, model Phaeton with 5 hp engine.
- 1909: Horch forced out of the company which changes of name from Horch ("listen" in German) to Audi ("listen" in Latin).
- 1924: First six cylinders model (4.7 Liter) models are produced.
- 1928: The company was acquired by Jørgen Rasmussen, owner of DKW
- 1932: Audi merged with Horch, DKW and Wanderer, to form Auto Union which later used the four interlinked rings that make up the Audi badge today, representing these four brands.

#### Audi cars

*Type E 1923*



*NSU 1200TT*



*Audi 100*



*2007 - Audi R8 with Full LED*



*2019 - Audi eTron with digital light*

## 2.2 Board Composition



**Markus Duesmann**

*Chairman, CEO, and Board member for Technical Development and Product Lines*

### "We take the crisis as an opportunity"

Audi's new CEO Markus Duesmann plans to seize the deepest industry slump in decades to make the automaker nimbler and restore Audi's technological edge after five years of management turmoil. He intends to review Audi's product lineup and speed up vehicle development.

"We take the crisis as an opportunity and even an invitation to try new things," Duesmann said.

The CEO was hired to revive profits at Audi after years of upheaval in the wake of the emissions-cheating scandal that erupted in 2015.

One of Duesmann's key moves since taking over at Audi was to set up an engineering task force called Artemis to develop a new electric car by 2024. Audi plan to cut as many as 9,500 jobs in Germany by 2025 to improve earnings by about €6bn.



**Arno Antlitz**  
*Finance, Legal*



**D. Grosse-Loheide**  
*Procurement & IT*



**Peter Kössler**  
*Prod. and Logistics*



**H. Wortmann**  
*& Digitalisation*



HR

**H. Wortmann**  
*MKT and Sales*

## 2.3 Audi Main Figures



**2019 Audi Group main figures** (also including 8,205 Lamborghinis and 53,183 Ducati motorcycles)

- Revenues: €55.8bn, down 6% versus 2018
- Operating Profit: €4.5bn up 27.8% versus 2018
- Profit after tax: €3.9bn up 13.9% over 2018
- Operating Return on Sales: up 8.1% over 2018
- Return on Investment (ROI): up 12.7% over 2018
- Net Cash Flow: €3.2bn

**2020 January to September:** integrating the decrease due to the pandemic

- Deliveries: 682,000 (versus 900k in 2019)
- Revenues: €33.3bn (versus €41.3bn in 2019)

## 2.4 Audi Vision and Strategy



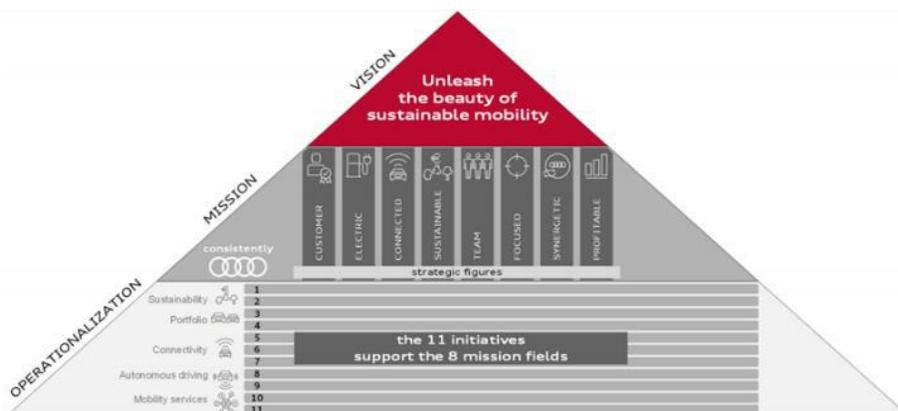
The Audi Group are among the world's leading producers of premium cars. They consider it a central mission to "unleash the beauty of sustainable mobility". Unpacking this; Audi consider "unleashing the beauty" to mean being the most progressive premium brand with the best customer experience, and being the brand with the greatest appeal, most fascinating customer-relevant innovations, and breathtaking design. As for the latter term, "sustainable mobility", to Audi it means:

- In the long term, CO<sub>2</sub>-neutral premium mobility.
- In the medium term, the strongest range of electric models amongst the premium competitors.
- By the middle of the coming decade, a million electrified cars each year.
- By 2025, reduction of the CO<sub>2</sub> footprint of the Audi fleet by about 30 per cent over the entire lifecycle.
- By 2050, to be completely CO<sub>2</sub>-neutral

This vision is operated with four goals:

The best-satisfied **customers**;

- Moving to the forefront of **electric** mobility (with 30 electrified models by 2025 including 20 pure EVs);
- Consistently **connected** by creating an open digital ecosystem, and
- Consistently **sustainable**: acting in harmony with ecology and economy conducting business transparently and integrity.



## 2.5 Main R&D Activities

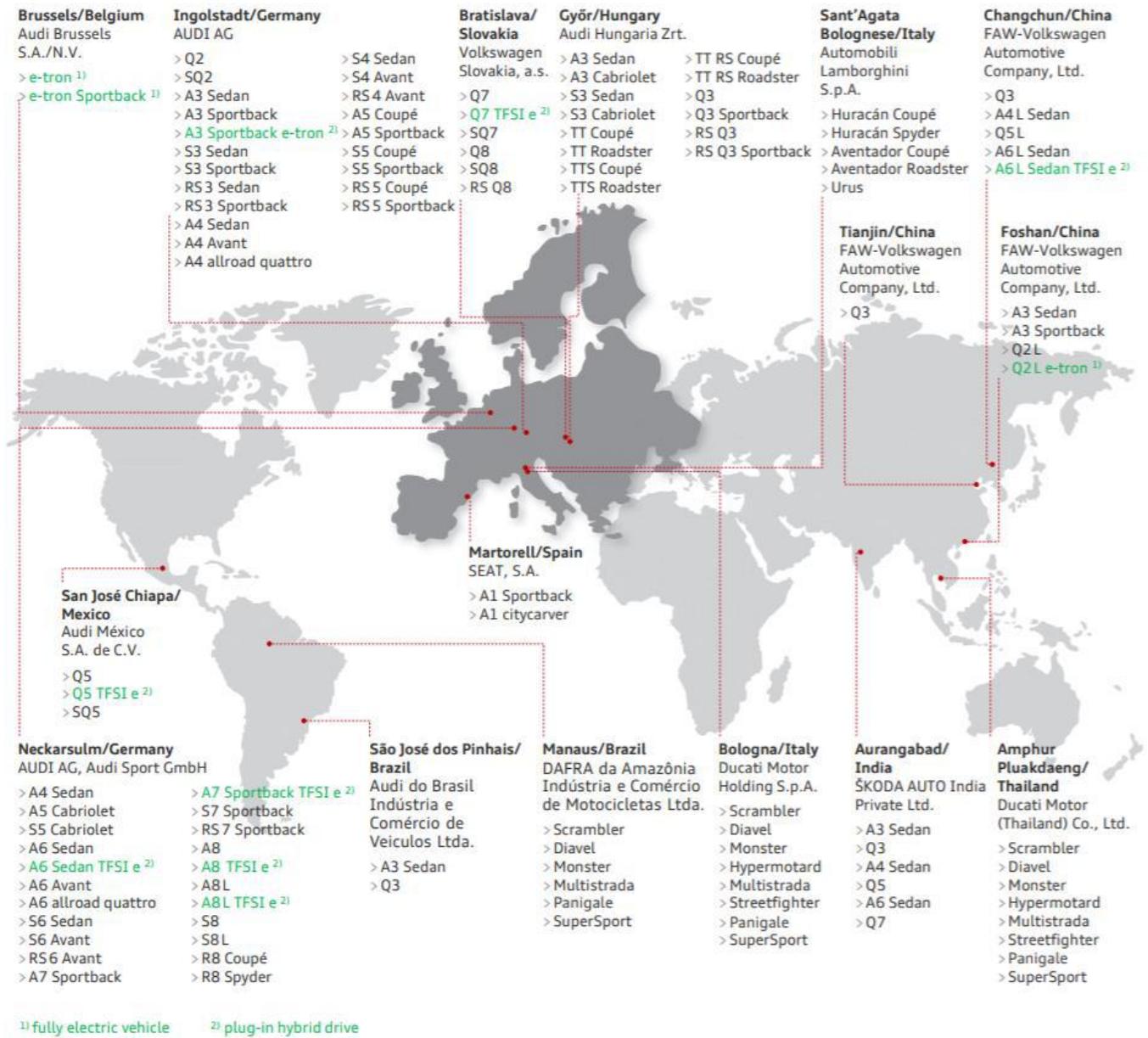
### Main R&D figures (2019):

- R&D activity costs: €4.4bn
- 15,000 people in Audi Group, including 12,000 at Audi AG.

### Main R& D directions:

- **Electric portfolio:** sustainability and efficiency by expansion of fully electric model range; development of a shared Premium Platform Electric (PPE) with Porsche, expansion of plug-in hybrid range, further development of h-tron fuel cell technology.
- **Driver assistance systems,** automated driving and artificial intelligence, further development of automated driving and complex driver assistance systems.
- **Audi Connect** and connectivity technologies: navigation with HERE map data, expansion of vehicle connectivity with its environment and of broadband connectivity (LTE Advanced, 5G).
- **User experience (UX):** development of adaptive user interface and optimum integration of third-party applications into the Audi ecosystem, development of new UI/UX technologies such as holography and new presentations of light and sound, development of empathetic vehicle with artificial intelligence, wellbeing and comfort, innovative displays with new technology.
- **Audi Design:** progressive, sophisticated design solutions for exterior and interior, development of new interior concepts that enable a range of application-based experiences for the customer.

## 2.6 Production Sites



## 2.7 Sales

### Car Production by Model

	2019	2018
Audi A1	-	8,750
Audi A1 Sportback	81,287	71,637
Audi Q2 <sup>2)</sup>	130,207	108,454
Audi A3 Sportback	128,788	171,729
Audi A3 Sedan	104,719	123,647
Audi A3 Cabriolet	7,302	9,571
Audi Q3	180,247	167,730
Audi Q3 Sportback	15,392	70
Audi TT Coupé	11,791	8,756
Audi TT Roadster	3,208	3,362
Audi A4 Sedan	228,113	244,484
Audi A4 Avant	85,790	86,548
Audi A4 allroad quattro	9,484	13,591
Audi A5 Sportback	71,128	80,162
Audi A5 Coupé	12,093	18,753
Audi A5 Cabriolet	9,856	12,629
Audi Q5	286,365	298,793
Audi A6 Sedan	176,362	195,270
Audi A6 Avant	50,677	51,990
Audi A6 allroad quattro	5,566	7,588
Audi A7 Sportback	17,068	20,058
Audi e-tron	43,185	2,404
Audi e-tron Sportback	191	21
Audi Q7	63,753	110,099
Audi Q8	44,890	22,414
Audi A8	23,826	24,541
Audi R8 Coupé	1,439	1,224
Audi R8 Spyder	682	540
<b>Audi brand</b>	<b>1,793,409</b>	<b>1,864,815</b>

Production by plant:

Audi Germany - Neckarsulm  
177,209 (186,196) Audi models.

Audi Mexico San José Chiapa:  
156,995 (173,734) of Audi Q5

Audi Hungary (Győr):  
164,817 (100,000)

Audi Brussels: 43,376 (66,286) The reason for the significant fall is the site's conversion to the production of electric vehicles.

Audi do Brasil São Paulo (Brazil)  
São José dos Pinhais, near Curitiba:  
2,346 (6,568) cars

In Volkswagen Group sites:

Spain—Martorell: 81,309 (83,629)

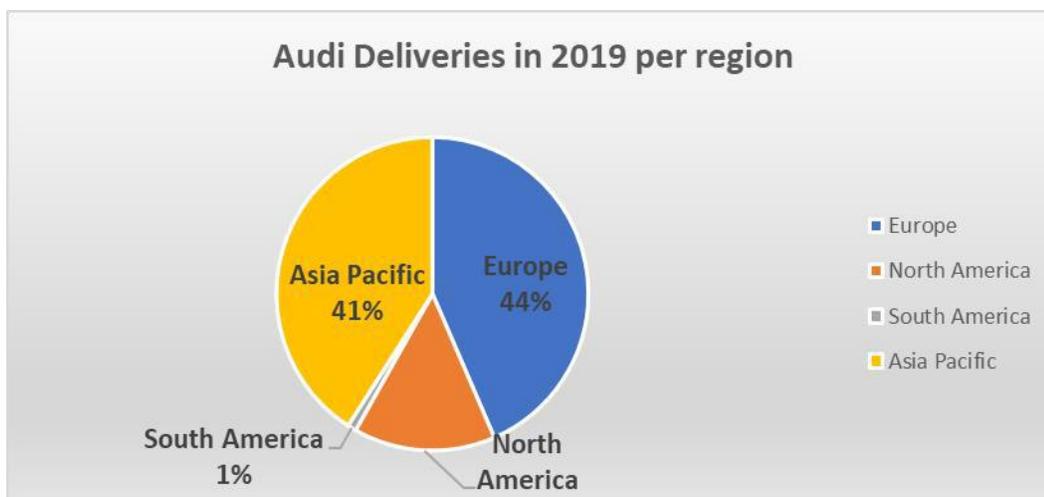
Slovakia - Bratislava: 108,198  
(131,758)

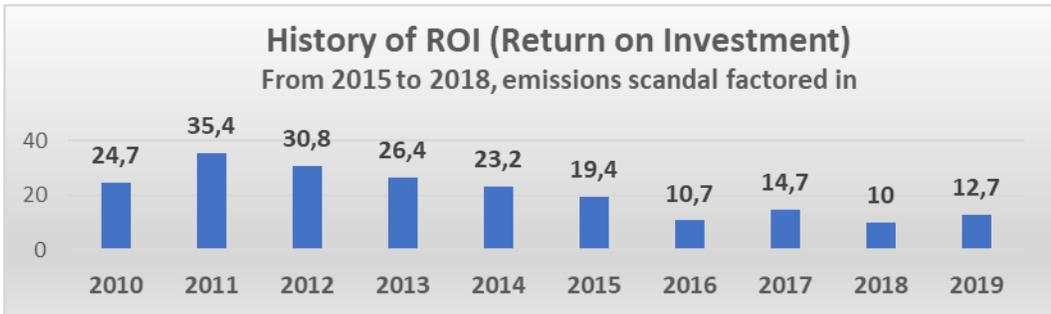
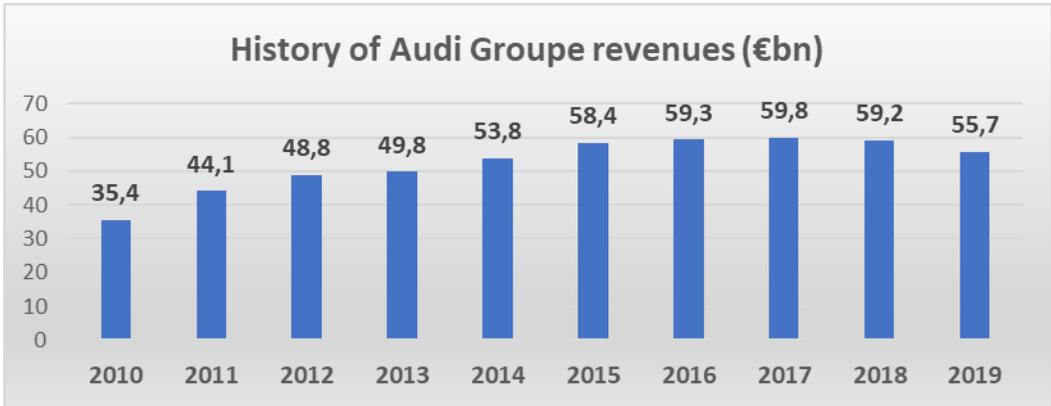
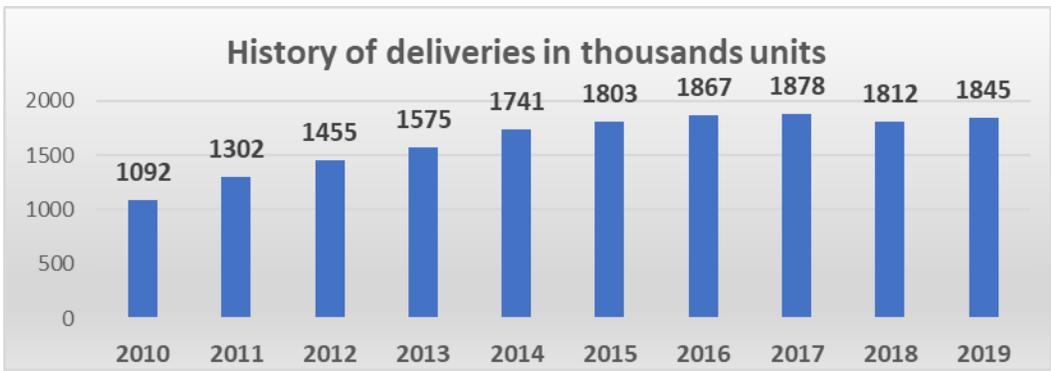
India: 2,715 (7,442) cars.

China - FAW Volkswagen  
Automotive Company, Ltd.,  
Changchun: 443,905 (511,177)

Foshan: 126,818 (106,647)

Tianjin: 44,113 (116)





## 3. Lighting at Audi

### 3.1 Introduction

#### A core competence

Audi's lighting people all along the process chain are very enthusiastic and knowledgeable. Lighting is a core competence at Audi. It is one of the strong points, deliberately made so as Audi picked lighting as a point of world leadership.

#### Two decades of Lighting development at Audi

2003: Audi adaptive light with automatic-dynamic headlight range control in Audi A8

2004: LED daytime running light in Audi A8 W12

2007: "String of pearls" DRL as a lighting strip in Audi A4

2008: Full LED headlights in Audi R8, now available across model ranges

2010: LED headlights with adaptive light in Audi A8

2011: Visually homogeneous LED rear lights in Audi A6

2012: Turn signal with dynamic indication in Audi R8

2013: Audi Matrix LED headlights with adaptive high beam in Audi A8

2014: Laser as additional high beam in Audi R8 LMX

2015: Opening of the Lighting Assistance Center with a light tunnel measuring 120 meters in length

2016: OLED rear lights in Audi TT RS

2017: HD Matrix LED headlights including laser as additional high beam in Audi A8

2018: Dynamic lighting scenarios: leaving and coming home functions in Audi A8

2019: Digital Matrix LED headlights (DML) in Audi e-tron and e-tron Sportback

2020: Digital DRL signatures in Audi A3 Digital OLED technology in Audi Q5

### 3.2 Lighting R&D Organisation

Since 1 November 2020, Stephan Berlitz is at the head of Audi's Lighting and Vision Systems Development department. He replaces Wolfgang Huhn, who headed that department for more than two decades.



*Wolfgang Huhn*



*Stephan Berlitz*

Of Berlitz, Huhn says *"Stephan Berlitz was my co-worker since nearly all my professional life. I know his way to work and his creativity and new ideas. He is the ideal successor as head of lighting in Audi. His way of leading people is cooperative full of respect to his staff and his*

colleagues. I am sure Audi lighting continues creating Innovations for heart and brain under his leadership."

### Lighting and Vision Systems Development team



*M. Hamm*



*C. Muntada*



*M. Kruppa*



*K. Schneider*

- Michael Hamm, head of front end lighting development
- Michael Kruppa, head of rear end lighting development
- Konrad Schneider, project management
- Cesar Montada, creative lighting designs

The team until end of December 2020:



*L-R: Selina Prenninger, Wolfgang Huhn, Stephan Berlitz, Michael Hamm, Konrad Schneider, Jana Flierl, Michael Kruppa*

**Good bye Wolfgang and congratulations; you have done a great job at Audi!**



### 3.3 Lighting Facilities: LAZ

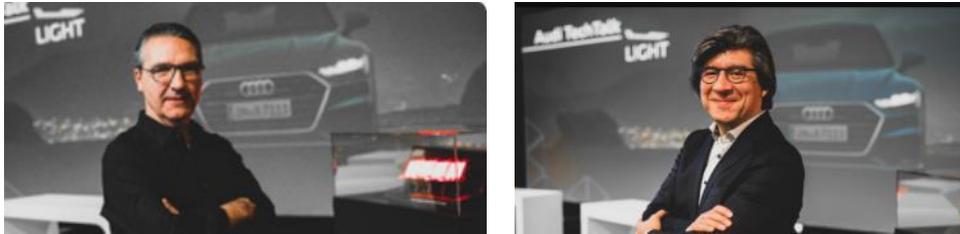


LAZ is made of two combined segments: Tunnel and “dome”.

- The tunnel has a total length overall of 120 m with a height of 5m, and a width of 12m. The ground is homogen and smooth as a road.
- The “dome” is the end of the tunnel, 25m long, with a height of 8 m, and a width of 18m. Turntable for light investigations and design purpose. Separate workshop for car preparations including light measument equipment,

## 3.4 Lighting Innovations

### Interview with Stephan Berlitz and Cesar Montada - December 2020



A talk between a developer and a designer of light : Stephan Berlitz, Head of Lighting Development and César Muntada, Head of Lighting Design.

They are closely working together in the development and design of lighting systems.

Their exchange shows how design and functionality at Audi go hand in hand.

#### **Uncompromising functionality of light and aesthetic design : are these two aspects compatible at all?**

**Stephan Berlitz:** At Audi, light, first and foremost, means safety for drivers and occupants, in other words, to see and to be seen. However, our highly functional technology, our HD Matrix LED headlights with the Audi laser as an additional high-beam light, provides scope for attractive styling as well.

**César Muntada:** Lighting technology and light design are inseparable at Audi. Light becomes the visible expression of 'Vorsprung durch Technik.' This means that we're giving the car an unmistakable face while sharpening the character of the model and brand. At night, an Audi has to be visible at first glance, both close-up and from a distance. Consequently, we use a principle that guarantees recognition without confining the scope which the character of a particular car requires. Specifically speaking, Audi creates a total lighting experience. It begins with the exterior and continues in the interior with contour ambient lighting for which the customer can choose the option of a customized color ambience.

#### **Legislation, restricts the potential of lighting development. How do you reconcile such differences?**

**Stephan Berlitz:** Each technology is subject to specific requirements in various countries. The statutory provisions worldwide stipulate minimum spatial, lighting and anti-dazzle requirements. Colors are regulated by law, depending on the light's function. In the taillight, Audi deliberately uses a vibrant red with a higher wavelength to generate a high-grade look and a more effective differentiation from the yellow turn signal. Generally speaking, though, along with a growing scope for functionality and styling, the complexity of the approval process increases as well and always requires an individual, country-specific assessment. The dynamic turn signal is a perfect case in point showing that legislators are receptive to good ideas. Audi convinced the regulatory authorities that this idea is a gain for road traffic safety. As a result, we succeeded in launching a world first. Many competitors subsequently adopted this function.

#### **Technological progress with hardware and digitization, are raising light to creating fascinating opportunities. What kind of changes does this entail for you?**

**Stephan Berlitz:** The significance of lighting technology is in a state of fundamental transformation. Due to consistent digitization, the perspective is expanding from driver-centric safety to comprehensive external communication and personalization. The utilization of light is changing: it is turning into a means of communication and, as a result, receiving a social and emotional component. Light will increasingly be able to indicate the intentions of the driver and the vehicle. We have smart, highly adaptive light control technology even today. Projections such as the marking light are an example of external communication with other road users. And the digital OLED, as well, shows how we can achieve car-to-x communication using light – a concept that may become even more important in the context of automated driving.

## **Light as a language for communication: How can on-road communication work completely without words?**

**Cesar Muntada:** Humans can grasp information particularly fast with their eyes. That's why we take advantage of the smart interaction between light and the surrounding area in our models. The objective is to achieve simple and direct communication that can be understood without words across cultures and around the world. Digitization will significantly help us in our efforts of setting light into motion and make this form of communication even more understandable. Take, for example, the wiping turn signal whose motion is reminiscent of the beckoning of a hand. In this way, light becomes a universal language in road traffic – both during daytime and at night.

## **Going forward, what prospects can you already share with us today?**

**Stephan Berlitz:** Over the next ten years, LED will continue to be the dominant lighting technology. In addition, there are two other lighting technologies. On the one hand, it's the laser light source, in other words, the continuing evolution headed for high performance. On the other hand, it's the OLED with its area-like, homogenous rear lighting that gives us great latitude. We're going to continue developing the digital OLED and complement it by new functions. In addition, we're already working on the next generation: the flexible digital OLED.

**César Muntada:** The flexible digital OLEDs provide us designers with new freedoms because they're bendable. This technology enables us to achieve an even better integration of the taillights into the vehicle contour and to generate three-dimensionality. The prospective communication between the vehicle and environment will be found in a combination of simple symbols and dynamic movements. In addition, we want to provide customers with light design styling options according to their personal tastes – in the future even more so than today.

Audi has been consistently driving progress in lighting technology for more than 20 years. What used to serve exclusively for the safety now shapes the visual appearance of every Audi model with its combination of design and technology. And with the digitization of lighting technology, this perspective will change even further in the future: towards even more personalization and comprehensive external communication.

## **How Audi reinvents light – How ?**

Originally, vehicle lighting mainly served the purpose of ensuring traffic safety for all road users. Light becomes a medium of external communication and interaction, personalizes design, and provides customers with new styling and customization options.

Lighting has made a veritable technology leap: The evolution from halogen light to Xenon headlights to LED technology in automobiles took less than two decades. These milestones of new technologies provided customers with noticeably added value.

As well as continually enhancing visibility, Audi lighting has been defining the face of the brand's models in every era while extending everyday usability by an equally communicative and aesthetic dimension.

Now, digitization provides another innovation boost with all-new design potential: Light is becoming smart. By means of light signals, the car interacts with its surroundings.

The introduction of the dynamic turn signal that allows indicated directional changes to be perceived of one's eye marked a significant gain in safety.

In 2017, Audi presented LED headlights featuring HD Matrix technology with the laser as an additional high-beam light in the A8 luxury sedan – a world innovation in large-scale production.



**Audi digital OLED technology**  
**Customizing lighting design and to be used for V2X communication**

Now, Audi is digitizing the Matrix LED headlight while adding even greater variety. The digital OLED rear lamps in the new Q5 have been opening the door to V2X communication since this year and, for the first time, make choices of new taillight designs possible at the time of configuring the vehicle. As well as intelligently illuminating the road, Audi provides its models with an unmistakable personality using distinctive signatures and dynamic lighting scenarios. Even at this juncture, customers are offered various model-dependent lighting signature options, to be followed by further differentiations.

The impressive scenarios of the leaving and coming home functions cause the light to strike an emotional chord..

### **The technology of LED light at Audi**

The technology of LED light introduced in 2008 was used by Audi to make a veritable quantum leap. It replaced the previously unsegmented and indivisible lighting units, significantly surpassing the efficiency, range and illumination performance of the previous headlights. In addition to this technical progress, LEDs permitted much higher degrees of freedom in designing the light source, so light as a styling element acquired much greater significance. Segmentation as a Matrix and digitization expanded the potential even further: The lights of an Audi no longer serve the mere purpose of providing illumination. They create a new customer experience by pioneering external communication including social interaction as well as enabling a wide variety of lighting design choices.

Today, headlights with LED technology are standard equipment in all model ranges, except for the Audi A1 as an entry-level model.

### **Technologies used by Audi, Laser, OLED, DMD, OLED**

In 2017, the A8 combined the latest ideas: Rear lights with OLED technology and HD Matrix LED headlights featuring the Audi laser as an addition highbeam light represented the benchmark among the competition. This is achieved by each headlight integrating two times 16 small, discretely controllable LEDs to generate a multi-row Matrix LED high beam. The system delivers cornering, urban and freeway lighting with maximum precision and complements the high-beam light by masking out other road users with enhanced accuracy.

In the Audi e-tron, the brand's first fully electric model, the digital Matrix LED headlight with a digital micromirror device (DMD) debuted in 2019. It marked another Audi success in launching a world innovation in the area of low-beam and high-beam lighting in large-scale production, because it was the first to feature the installation of DMD technology that had its origins in video projectors in an automobile. At its core is a small chip that integrates 1.3 million micromirrors, each with an edge length of just a few hundredths of a millimeter. Depending on the position, the light from three high-performance LEDs reaches the DMD chip in concentrated form via specifically calculated lenses and a free-form reflector. From there, the light hits the road either via lenses or an absorber that masks it out.

This goes hand in hand with as many as three innovations delivering high customer value.

- 1) The technology is able to project a kind of "light carpet" in front of the vehicle when traveling on expressways such as the autobahns in Germany. This so-called lane light brightly illuminates the vehicle's own lane, dynamically spreads when changing lanes, and thus enhances traffic safety.
- 2) The orientation light facilitates lane-keeping especially in narrow sections by indicating the vehicle's position in its own lane as a strip-like boundary.

3) Used in combination with the optional Night Vision Assist feature is the marking light. It detects pedestrians close to the roadway and alerts the driver to them by means of a precision light cone.

### **Rear light technology at Audi**

OLED rear lights on the Audi TT RS started in 2016. The light of the light-emitting diode is extremely homogeneous and precise. This technology is efficient, lightweight and visually impressive. In 2020, Audi was the first manufacturer to digitize the rear lights that turns them into a display and opens up new potential in terms of styling, personalization and safety. Due to the increased segmentation of the digital OLEDs to currently 18 segments, diverse rear light designs can be achieved for the first time.

Customers purchasing a Q5 can choose between three rear light signatures. Irrespective of these choices, a particularly sporty signature can be set in “dynamic” mode in Audi drive select. In addition, the proximity indication feature enhances traffic safety: When the Q5 is standing still and another road user approaches from behind at a distance of less than two meters, all OLED segments are activated. As a result, the visible area is enlarged and perceptibility enhanced. A total of five different visual lighting patterns can be achieved here with just a single set of hardware.

### **Welcome and Farewell at Audi**

In 2004, LED DRL defined Audi’s face for the first time while enhancing visibility. Today, on the A3 as the first model range, Matrix LED headlights can feature model- and line-specific signatures in the DRL using just one set of hardware. The dynamic lighting scenario of the leaving and coming home function in the Audi A7 Sportback and A8 created a new customer experience. This function is activated when unlocking and leaving the car. The digital Matrix LED headlights with DMD technology for the Audi e-tron are now offering five different welcoming versions within the range of extended dynamic lighting scenarios. They can appear as projections on a wall or on the ground. With such diversity and innovative prowess, Audi has been and will remain not just the globally leading brand in automotive lighting technology, but also makes this type of “Vorsprung durch Technik” visible in the design of lighting signatures and their dynamic enactment.

### **Versatile and forward-thinking**

Safety, communication and interaction Light at Audi stands for a symbiosis of technology, design, safety and customer experience. Connectivity ensures smart functionality. Lamps turn into displays and a one-dimensional signaling and warning function of the past will evolve into a versatile means of communication with the external world, going forward. Be it at the front or rear, thanks to freely selectable signatures with identical hardware, a wealth of variety has found its way into the brand’s model ranges. Going forward, it is conceivable that, via the MMI, owners will be able to switch between a wide range of signatures or achieve custom designs. Via the myAudi app, Audi e-tron customers already have the opportunity of booking additional lighting functions even after having purchased their car – anytime and with great flexibility. Other models will follow. Today, the digital Matrix LED headlight with DMD technology already offers projections for specific lane guidance and orientation, which serve to make driving easier and avoid accidents. As a forward-thinking prospect, this technology, combined with other ideas, may enhance the driver’s attention as well as mutual consideration and respect among road users.



Since 2020, the proximity indication feature in the Audi Q5 has made V2X communication of the rear lights a reality as well. Hence Audi is pursuing an anthropocentric path and, with the digital OLED rear lights, paving the way into a new age. The rear lights are evolving into a display medium, which can be extended by versatile functions in the next evolution. In the medium run, the digital OLED will have more than 60 segments, each of which can be individually controlled and systematically activated. Looking forward, besides enabling the versatile styling and personalization

of lighting designs, the digital OLED, for instance, will be able to issue early warnings of local hazards such as slippery roads and the end of traffic jams to other road users.



Looking forward even further, Audi is working on the flexible digital OLED. Instead of the roughly 0.7 mm thin yet rigid supporting material, flexible substrates such as thin glass, plastic films or metal foils may be used, which can be bent in one or several directions. This new potential provides greater styling freedoms for rear light designs. The technology's key characteristics are retained as well as the low weight of the existing two-dimensional OLED displays.

For the first time, the light emitted will be able to shine in a three-dimensional way. Flexible digital OLEDs facilitate the integration of the "display area" all the way into the vehicle's flanks, thereby visibly enlarging the usable area for lighting design and communication with the surroundings once again.

### 3.5 Interior Lighting

#### Interior lighting with driver inside

Certain light sources in the interior can increase active safety when driving at night by allowing the eyes to adjust more quickly to changes when switching from the road to the interior. This was the result of a study carried out in conjunction with the Technical University of Darmstadt in Germany. These findings have been realised in the form of Audi's interior lighting packages. The permanent vertical illumination of controls as well as the centre console and door trim panels makes contrasts visible that are important for operating reliability and orientation in these areas. Thanks to the positioning and choice of light sources, there is no risk of the driver being distracted. Moreover, the driver can configure brightness and lighting profiles by means of the "ambient lighting". The interior lighting package includes the illumination of door pockets, footwell, and inside door handles using LEDs. Swivelling reading lights are located in the rear roof module.

Future interior lighting will be very strongly software-driven. Carmakers will define their special orchestration of interior lighting with defined interior component functions, and develop their own software in their IT departments. Suppliers will be more responsible for hardware components with a defined interface. But if the suppliers have enough software and electronic competence, then they can deliver the complete hardware and software. In this case it is necessary that the cooperation of automakers and suppliers starts in a very early phase of car development, because the interior lighting concept has to be developed as part of the component concept.

#### Great potential of interior lighting

Nearly all carmakers round the world have detected the great potential of interior lighting to improve psychological and physiological effects for more safety, comfort, orientation, signaling, information, entertainment, communication, working, wellbeing, space-feeling, to set brand identifiers and to amplify styling highlights in the car interior. The control of the interior lighting becomes more and more intelligent by combining lighting functions with cameras, sensors, and the electronics of the vehicles. Autonomous driving is also accelerating the development of new interior lighting features and technologies, because the passengers can enjoy new pastime opportunities and individual freedoms in a rolling combination smartphone, office, living room and "wellness oasis", to use Audi's terms.

For Audi, the megatrends for automotive interior lighting to support future use cases are:

- Connectivity and digitalisation for enhanced interaction with the environment

- Individualisation with personal light solutions for each passenger
- Efficiency and electrification with low-power technologies
- Smart matrix and zone lighting for each passenger
- Adaptive lighting for different seat positions and activities
- Working and reading light with adapted brightness and light distributions
- Light beam for hand guidance and orientation
- Individual lighting for wellbeing, relaxing, warning or strengthening vitality
- Individual lighting to combat fatigue or motion sickness
- Lighting for privacy with darkened windows
- Lighting for augmented communication
- UV light for disinfection of the cabin
- Combining of light with infotainment and other interior functions

### 3.6 Audi Model Range

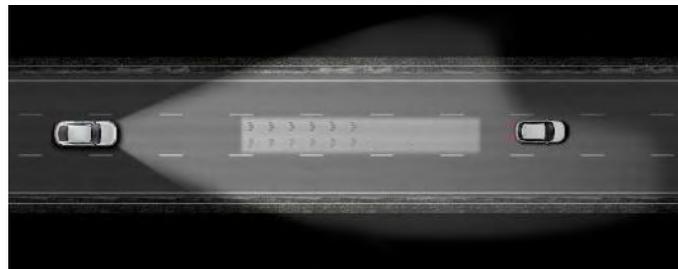
No halogen in any new Audi models except A1

e-Tron is the first Audi model with matrix in Entry and with DMD in option

A5 to A8 and Q7-Q8 use Matrix in Entry

#### e-Tron

In the e-tron Sportback, the digital light generates dynamic leaving and coming-home animations that appear as projections on a wall or on the ground. This presentation transforms the area in front of the car into a carefully illuminated stage. The digital light system delivers cornering, city, and highway lighting as versions of the low-beam light with exceptional precision. It also supplements the high-beam light by masking out other road users with even greater accuracy.



*e-tron Sportback: lane and orientation light from digital matrix*

It offers innovative functions such as lane light and orientation light. On freeways, the lane light creates a carpet of light that illuminates the driver's own lane brightly and adjusts dynamically to lane changes. In this way, it improves the driver's awareness of the relevant lane and contributes to improved road safety. In addition, the orientation light uses darkened areas masked out from the light beam to predictively show the vehicle's position in the lane, thereby supporting—especially on narrow roads or in highway construction zones—the safe lane centring assist.

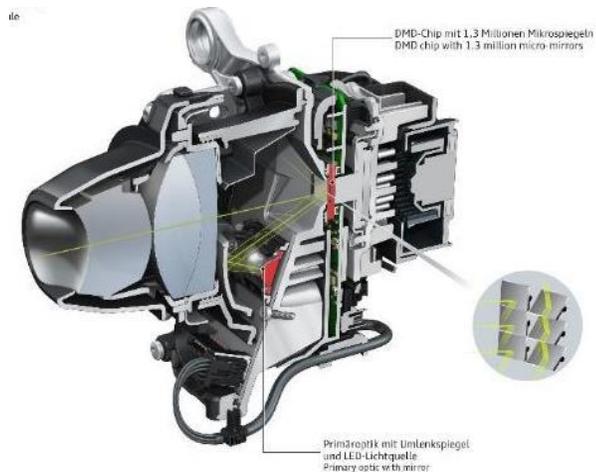
The marking light function is also used in conjunction with the optional night vision assist. The light automatically draws attention to any pedestrians it detects, thereby reducing the danger of overlooking pedestrians in the immediate vicinity of the lane.



*e-tron Sportback*

The design is based on DMD technology (digital micromirror devices) also used in many video projectors. At its heart is a small chip containing a million micromirrors, each of whose edge length measures just a few tens of  $\mu\text{m}$ . With the help of electrostatic fields, each individual micromirror can be tilted up to 5,000 times per second. Depending on the setting, the LED light is either directed via the

lenses onto the road or is absorbed in order to mask out areas of the light beam.



### **Digital Matrix LED module**

On freeways, the lane light creates a carpet of light that illuminates the driver's own lane brightly and adjusts dynamically to lane changes. In this way, it improves the driver's awareness of the relevant lane and contributes to improved road safety. This option costs €4,000. It can illuminate a carpet of light onto the motorway lane which the car is travelling. The projection is apparently constrained by the white lines, and curves with the topography of the road. Onto this light-carpet two lines of chevrons show the exact width of the car including door mirrors—useful for adjudging gaps in traffic or goalposting between narrow roadworks.

### **Interior Lighting**



Extensive contour lighting, combined with indirect multicoloured ornamental lighting in the door panels

## A1

This is the second generation of Audi's successful compact car. The distinctive DRL graphics of the optional full-LED lights echo the dynamic wing shapes from sailing, known as hydrofoils.



The design of the shutters for the main light functions also draws inspiration from sailing. The wing segments on the flanks create an impression of maximum width. A low-set, concentrated look in conjunction with the small rhombus segments in the top section of the headlamps provides a sporty appearance.



The dynamic segmentation motif also features in the rear lights to reinforce the instant recognisability of the A1 light graphics. It is encased in the striking 3D geometry of the lens. The seamless light pattern of the graphics in the dark constitutes a remarkable feature of the two-part rear lights.

### A3

Audi entered the premium compact class segment with the A3 in 1996. The fourth generation of the successful model is now being introduced, and it is at once sporty, digitalised, and fully connected.

The digital DRL of the matrix LED headlamps consist of a pixel array made up of LED segments to create special light signatures and make the A3 immediately recognisable.



The headlamps are available in three versions. Even the basic version uses almost all LED technology. Their flat, wedgelike shape underlines the car's sporty character. Trapezoidal angles at the outside corners are drawn downward. The top-spec matrix LED headlamps integrate a lighting innovation from Audi in these angles: the digital DRL. Their matrix of LED elements in a three-by-five arrangement can be actuated variably, so different versions of the A3 each have specific signatures. While horizontal lines are characteristic of the basic model, two vertical LED lines emphasise the sportiness of the S line exterior. In addition, the matrix LED headlamps offer intelligently controlled, anti-glare high beam light, dynamic turn signal light, and many other functions, including new animations when the car is unlocked and when exiting the car.



## A4

The A4 represents the core of the brand, and the latest version of this successful midsize model is taut and sporty.



The new headlamps in the Audi A4 are available in three versions. They feature LED technology from the basic level, apart from the indicators. The first option includes LED headlamps with additionally upgraded daytime running lights, a daytime running light signature, additional functions such as freeway and intelligent cornering lights, and dynamic rear turn signals. In the upper part of the headlamps, one long and five short light lines make up the contour of the daytime running lights.

As the top-of-the-line system, the matrix LED headlamps also provide dynamic indicators and cornering lights as well as an animation. Their fully automatic high beam is radiated by eleven LEDs in each headlamp, which sit behind a lens and, just like the adjacent low beam module, have the appearance of an eye. The control unit can switch them on and off or dim them as necessary so that the matrix LED headlamps always illuminate the road brightly without dazzling other road users. When car is locked and unlocked, dynamic light animations play in the headlamps and rear lights.



The A4 rear lights are available in three versions. They, too, are all equipped with LEDs as standard. With the first option, the customer receives the LED rear lights with a specific signature based on the motif of the daytime running lights, and dynamic indicators. In the highest configuration level, the tail light comes with the coming home / leaving home animations just like the headlamps.

## A5



All A5s have LED headlamps as standard equipment. Matrix LED headlamps with LED rear lights featuring dynamic turn signals are an optional upgrade. The top lighting package includes matrix LED headlamps with a laser high beam booster, LED rear lights with dynamic turn signals, and dynamic light sequencing.



The A5's rear lights feature a 3D lens, here again with a signature and form inspired by the hydrofoil. The 3-striped signature aligns with the new Audi signature, bold and graphic.

## A6



The A6's lighting design emphasises the technical character of the car. Three headlamp versions are available up to HD matrix LED technology with high resolution, dynamically illuminating high beam. Five horizontal lines draw the daytime running light signature; above them are the low beam modules that look like pupils.



The rear lights also include the dynamic indicators, and the lights stage the pulsing coming and leaving home functions when unlocking and locking the doors. A contour ambient lighting package is available for the interior, which makes the dashboard and the centre console appear to float.

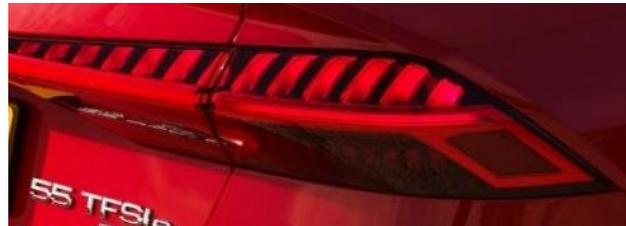
## A7

The A7 Sportback is a new style of Gran Turismo, offering systematic digitalisation and a space concept that combines a wide range of customer requirements. The large four-door is a high-purity expression of Audi's new design language.



The A7 Sportback bristles with evidence of Audi's leading role in lighting technology and lighting design. The car's headlamps are available in three versions, all with LED technology: basic; as HD matrix LED, and as HD matrix LED with laser high beam booster. In continuation of the top slat of the single frame, the two matrix variants are divided horizontally to make the headlamps appear slim and sporty. The dominant upper area houses the daytime running lights and creates a look with plenty of character.

The low beam module is in the "pupil." With the two HD matrix variants, the daytime running light signature is digital in character: twelve light segments are positioned vertically, side by side, separated by narrow spaces—conjuring up an association with the 0 and 1 of the digital domain. In the lower zone are the turn signal and the two-line matrix high beam, which comprises 32 individually-controllable LEDs. They illuminate the road dynamically and precisely while shadowing other road users out of the beam to avoid dazzle. The LEDs also act as cornering lights. With the top-of-the-line headlamps, the lower segment also includes the laser spot with its X-shaped metal aperture and the blue light guide. The laser spot is activated when the high beams are on and the car exceeds 70 km/h; it doubles the range of the high beam.



The tail light of the big car also seems to be digital. Each unit has 13 vertical segments that alternate with the brake light, which is also segmented. The LED light strip interconnects them. As on a racing car, the rear fog light is positioned in the centre.

## A8

Lighting technology in the new A8 interacts intelligently with the surroundings. For example, Audi's laser high beam booster is used here for the first time with HD matrix LED high beams.



The laser spot is identified by an X-shaped shutter and blue ambient lighting. The DRL with the vertical segments emphasises the technical elegance of the headlamps. Each HD Matrix LED high-beam unit consists of 32 small, individually controlled light-emitting diodes that project the light in two lines.

The high-precision control for the HD Matrix LED high beam is based on data supplied by the front camera. Cornering light is produced by displacing the light's focal point. It uses navigation data to shine into a bend just before the steering is turned. The junction light likewise comes on predictively just before a junction is reached. The segmented turning light also comes on dynamically in three stages up to a maximum angle of 90°. With all its functions complete with dynamic turn signals, each HD matrix LED headlamp incorporates 138 LEDs and one high-performance laser diode. The innovative automatic lighting prevents incorrect operation and is controlled from a new light switch module with proximity sensors and touchscreen surface.



Audi's OLED rear lights emit extremely homogeneous light. There are four ultra-flat OLEDs floating in each module, sub-divided into four individually controlled segments. Two on each side form the angular tail lights, and the other two act as the brake lights. Below the OLEDs there is also an LED light strip that adapts to ambient brightness when the brakes are applied. The same goes for the dynamic turn signal lights positioned directly below them. There are 135 LEDs in each rear light.

### Interior Lighting

Great potential for customer satisfaction is found in the car's interior lighting package. For example, the rear seat compartment: ordinary illumination lights the full area of a reading plane; different placements of passengers or different need for reading areas could not be served individually. Matrix technology to the rescue; just like it shape-shifts the headlight beam, so too the lit areas can be shifted according to the needs of the passenger. In one interior lighting module, for each passenger side, an array of 7 LEDs adapts the illuminated area to the needs for reading or other visual tasks.

A video presentation of the animated effect is [available online](#).

## Welcome light

Many LEDs help to animate the switch-on of the headlamps and rear lamps of the Audi A8. Unlike a



conventional double-blink of the turn indicators to show the unlocking of the car, in the A8 there is a lighting spectacle. After the wiping turn indicator shows the unlocking, the DRL "unfolds". Like at the cinema, the sequential switching on of the LEDs creates an eyecatcher and also creates a smile on an observer's face. In the rear lamps, the OLED segments are sequentially activated after the large LED line finishes—a red spot running through the complete rear lamp.

## Q2

Headlamps and rear lights draw attention to the new Q2 with light sequencing when the car is locked and unlocked.



Audi's Q2 compact SUV has fancy new headlamps—all versions in LED technology, with matrix beams available as an option. Seven individual LEDs seated in a shared module produce an intelligently controlled glare-free high beam. 10 LEDs installed behind rhomboid optical components generate the DRL, and seven additional LEDs generate the sequential turn signal.



For the rear lights, customers can choose between two LED versions: with or without sequential turn signal—but if the matrix LED headlamps are selected, the sequential-turn tail lights come along with.



The interior design echoes the design of their exterior. With the optional Ambient Lighting Package Plus, the trim strip on the instrument panel and the knee pads on the centre console feature elegant backlighting.

### Interior Lighting



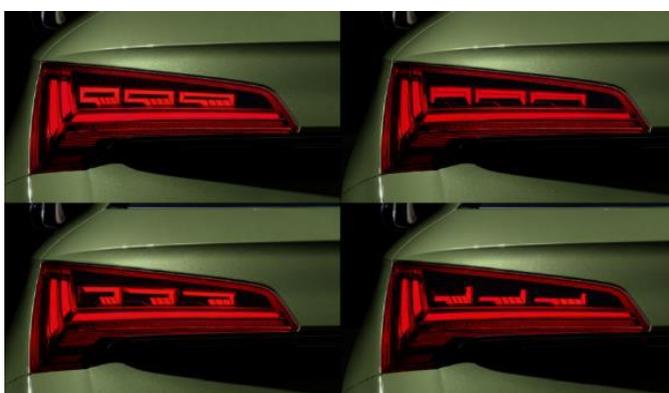
Illuminated decor trims and indirect lighting in door panels, illumination in dashboard and below centre console

### Q5

The upper section of the LED headlamps features a new signature for the DRL. Customers can upgrade the LED headlamps to matrix LED headlamps with automatic main beam. They have the option of "buying" certain options even after they have bought the car. When the car is eventually sold or traded in, Audi can zero-out the features again so that subsequent buyers will have to pay for them, too.



The sharpened exterior design of the Q5 emphasises the Q identity and boasts a rear light cluster featuring digital OLED technology for the first time worldwide. The optional OLED taillights' homogenous light surface is divided into three tiles of six segments each, which enables Audi designers and developers to create different light designs and signatures from a single hardware assembly. When ordering their Q5, customers can choose from three rear-light signatures, each with its own specific designs for the welcome and farewell animation.



When the driver selects "Dynamic" drive mode, the taillights change to yet another signature, and the taillamp cluster has a proximity detection: If a road user approaches a stationary Q5 from the rear to within less than two metres, all the OLED segments light up.

These services, called Functions on Demand, are booked via Audi's digital platform myAudi. Previously, customers had to configure optional

equipment when ordering a car. From now on, there is also the additional option of flexibly activating functions in the areas of lighting, driver assistance and infotainment after the purchase or reloading them via OTA transfer.

## Q5 Interior Lighting



## Q7



The Q7 is equipped with LED headlamps as standard. Matrix LED headlamps constitute the first basic option; HD matrix LED headlamps with laser high beam booster can also be had, each of which features 64 LEDs and a high-performance laser diode. The laser module can be identified by its X-shaped contour with a blue fascination LED. Arranged in two rows one above the other, the high beam of the HD matrix technology illuminates the road precisely and dynamically. Individual light segments are switched on or off so as to prevent other road users being dazzled.

The LEDs also act as cornering lights, created through a displacement of the light concentration following the contour of the bend. This occurs already shortly before the wheel is turned, based on the predictive route data from MMI navigation plus. The intersection light also goes on predictively just before an intersection is reached. Furthermore, the turning light extends the lateral illumination up to a maximum angle of 80 degrees. The daytime running lights, which are divided into small vertical segments, have a three-dimensional effect. Just like the rear lights, the headlamps incorporate the dynamic turn signal and provide an animated dancing-light show when the car is locked or unlocked.



Horizontal tail lamps extend far into the sides. The rear light signature echoes the design of the DRL signature up front.

## Interior Lighting



Contour lighting in door panels and centre consol, indirect lighting in dashbord and centre console.

## Q8



For the headlamps, Q8 customers can enjoy the benefits of High-Definition matrix LED headlamps fitted as standard, with dynamic front and rear turn signals and an impressive light show during locking and unlocking. In future, Q8 owners can use the myAudi app on their smartphone to activate various lighting functions and experience them from the outside. Each headlamp unit consists of 24 individual LEDs and, from afar, the two-part lights appear very flat, as only their top part is visible.

They integrate the daytime running light and the low beam, among other functions. The high beam is positioned underneath, darkened and offset to the back. The daytime running light signature with digital character comes in a strongly three-dimensional design for the first time. It consists of seven short segments and two longer ones at the edge of the headlamp. The latter shift the visual focus to the outside, highlighting the width of the car.



The taillight uses a similarly three-dimensional design with its twelve segments, connected by the distinctive light strip which simulates depth.

### Interior Lighting



## 3.7 Audi Suppliers

To sustain relations with suppliers that are successful for both sides, Audi have created a process known as Audi Value Management. The aim is to achieve a balanced relationship between customer value and budget. Technical elements and production processes should be coördinated such that Audi can realise these goals cost-effectively while offering the customer a high value of benefit. The key to this is a systematic product creation process that involves suppliers closely and at an early stage. In this way Audi want to guarantee transparency, trust, and adherence to deadlines, top quality and plausible cost management.

### Feedback of Audi Lighting Suppliers

DVN asked questions below to the Audi suppliers

#### Differences between Audi and other car makers:

Audi is different because there is a very high level of engineering know-how including focus on robust design products,

They are looking always for new solutions in each generation, and they are driving and knowing how to handle first to market applications.

Audi combine a deep understanding of the technology with high level of expertise, and a good project management. They are very agile in the way they manage application projects.

It makes them successful to introduce sustainable innovative technology in the market.

#### What do suppliers like working with Audi:

Collaborative partnership, open communication, and fast response. The excellent understanding of technical content facilitates decisions. They are always driving solutions focusing on the technical content. Audi act as a real partner with their supplier and they support us to solve issues and create a trusting and demanding relationship which is a great source of motivation for our team.

#### What characterises Audi in lighting

Innovative and great design, challenging the status quo, striving for excellence.

Technologies focus to signature by light, DRL, matrix beam, laser, OLED, full width rear lights, HD lighting, and now customisable pixellated signature.

### Collaborations

#### • Elmos

Elmos Semiconductor and Audi are extending their partnership for LED rear light control and have unveiled sample availability of the new IC E522.95 multichannel LED controller for exterior lighting with network interface capabilities allows direct control of LED lamps. Equipped with a 2Mbps CAN FD protocol and a CAN FD physical interface, the E522.95 can be connected directly to the Body Control Unit (BCM) via the car's in-vehicle network, with Elmos maintaining local lighting control units are no longer needed.

Audi Electrics & Electronics Executive VP Klaus Büttner says "Enabling direct control between the BCM and LED lamps marks an important step towards realising centralised car lighting and domain driven architectures considered essential for styling, customisation, dynamic animation and autonomous drive by removing the need of localised lighting control units and thereby resulting into significant system cost savings and above all full application flexibility".

#### • OLEDWorks

"Predevelopment collaboration" to advance OLED lighting technology in automotive applications. Audi and OLEDWorks will work together to use OLED lighting and implement it in Audi's future vehicles.

- **STMicroelectronics**

In partnership with Audi, STM are working toward next generation innovative automotive exterior OLED lighting solutions.



The current coöperation expands the relationship and builds on Audi's creativity and success in automotive lighting solutions and STM's broad expertise in automotive semiconductors, and specifically controllers and drivers for automotive lighting applications. The next-generation lighting design will enable more customised and animated lighting patterns, by

controlling and diagnosing hundreds of individual OLEDs.

In the recent ISAL demonstration presented by Audi, STM contributed a complete plug-and-play system to control and continuously adjust the brightness of the numerous individually energised OLED pixels by means of an innovative high-speed automotive communication layer, specifically adapted by ST for lighting architecture and embedded in the actuator IC.

### 3.8 Audi Lighting at Conferences and Workshops in 2018-2020

Audi is present at all events concerning lighting, making presentation dedicated to styling and technology. Below, a summary of 8 interesting presentations in the last 3 years, only two in 2020 because Covid. pandemic.

#### DVN WS Munich 2018

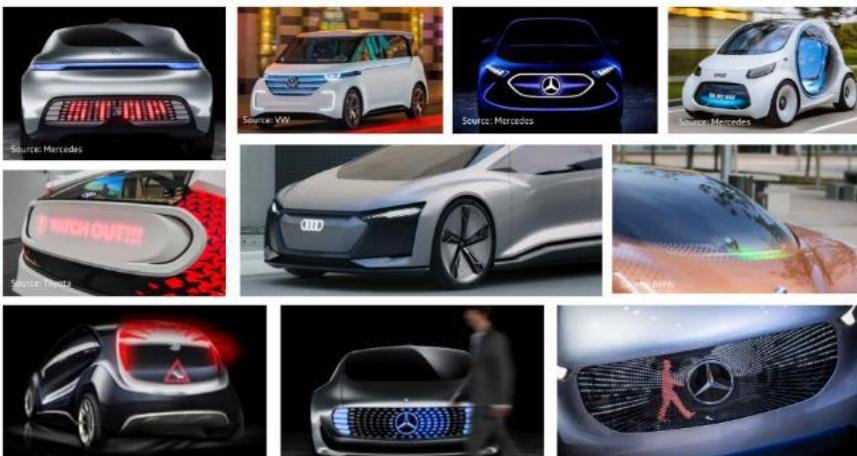
##### New aspects in lighting for autonomous vehicles

Wolfgang Huhn, Audi Lighting & Vision General Manager

Mega trends: Digitalization, Urbanization, Sustainability

Light for Automated Driving Possible lighting signals

#### Light for Automated Driving Possible lighting signals



#### DVN WS Tokyo 2018

##### Communication Lighting – Status and Outlook

Wolfgang Huhn, Audi Lighting & Vision General Manager

Dr. Huhn's presentation had three main parts analysis of the Uber collision, possibilities with the construction-zone light function, and comments on GTB's strategy.



About Construction Zone Light with Digital Matrix Light, Audi showed the prospects and possibilities offered by a new construction zone light function to guide drivers through tricky roadworks.

#### VISION Paris 2018

##### An OLED Taillight Revolution – From Point Light Sources to Area Light Sources

Michael Kruppa, head of rear end lighting development

OLED can be applied in automotive without any risk. BMW, Daimler, and Audi are using this technology in an impressive manner.



### **Audi A8 Hybrid approach vs 100% OLED at Daimler**

To further push the substitution of LEDs in tail lamps by OLED a significant cost down program is needed. By DTC and module based approaches OLED will reach a highly attractive cost situation to further roll out the light source of the future. New functions are already been implemented which can only be applied by OLEDs and no other light source. The revolution has just began – be part of it.

### **DVN WS Rochester 2019**

#### **Research Findings on Digital Light Technologies DVN WS Rochester 2019**

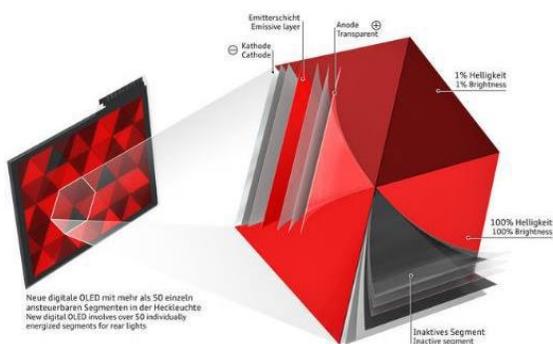
Michael Hamm, Audi Manager Development Headlamps

- Matrix LED headlights are Adaptive Driving Beams or Glare Free High Beam. Each segment is individually dimmable and switchable.
  - ADB systems are on the market since 2010 and the total km driven by NIGHT with ADB cars in 2018 is more than 5,820 million km. So, ADB according to ECE R.123 has passed the largest imaginable field test
  - Modern LED lamps have about 50% higher Zone A (TC 4-45) rating than Halogens.
  - ADB systems can deliver between 50% and 130% more object detection distance than LED.
  - LED systems and ADB systems produce less glare than conventional Xenons
  - It can be assumed that ADB systems have even better impact on traffic safety than only Xenon
- ADB systems are on the market since 2010

### **ISAL 2019**

#### **Next generation of OLED lighting technology**

Audi presented insights into the next generation of OLED lighting technology. The new digital OLED technology enables customisable lighting designs and allows communication via a vehicle's exterior lights.



#### **OLED technology**

The first series production of Audi OLED technology in 2016 was in the tail light of the TT RS. In contrast to point light sources such as LEDs made of semiconductor crystals, the OLEDs are surface radiators. Their light reaches a homogeneity on a new level and can be dimmed steplessly. It does not cast shadows and does not require reflectors, optical fibres, or similar optics, making the OLED units very efficient and lightweight. Another advantage of OLEDs is the possibility to divide them into small

segments that can be controlled with different brightness. The OLED lights can also implement animation effects in Audi models such as welcome and farewell light displays.



### ***OLED technology with individually-controllable segments***

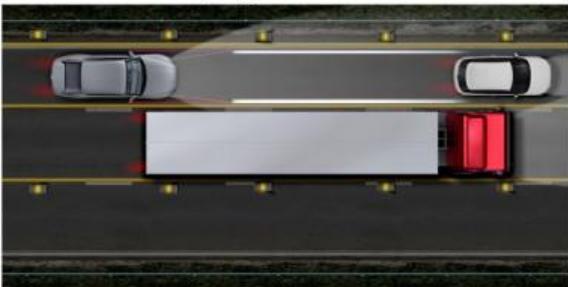
The high system efficiency as area light in a millimetre-thin light element is retained. The digital OLED is therefore the perfect technology to present personalised lighting design with high precision and great variability. In addition to the versatile design of lighting designs, the digital OLED can be used as a display element in the rear lighting and thus as a V2X communication element. For example, pre-defined icons may be displayed to alert other road users early to local hazards such as slippery roads or an upcoming traffic jam.

### **ISAL 2019**

#### **Real Driving Benefits and Research Findings with Digital Light Functions**

Michael Hamm, head of front end lighting development

Digital lighting functions are supporting the driver's comfort and safety. Especially with construction zone lighting (CZL) the effects are visible with recordable physical parameters. The steering wheel corrections are reduced and the gas throttle position is kept about 15% more unchanged in a construction zone.



All experiments and measurements showed that the digital light projections do not create additional subjective glare compared to a standard low beam light distribution. There have been concerns about such negative effects. This study completely refutes such concerns. The results that digital light does not create additional glare was approved valid for dry roads, wet and very wet road conditions. As shown, there are many positive safety effects from digital light.

### **DVN Munich Workshop 2020**

#### **Audi's OLEDs**

Wolfgang Huhn, Audi Lighting & Vision General Manager

For rearlamps, OLED solutions are still pushed by Audi, with specific solutions not possible with LEDs.



***View digital business models***

LEDs are however extended their styling domain with new solutions for instance textiles for new appearance or new 3D appearance solutions

Displays for dynamic rear lighting or for communication are developed by several companies despite the fact that the current regulations are not allowing this.

**DVN online Workshop 2020**

**Activity Report - GTB Strategy WG**

Wolfgang Huhn - Audi Lighting & Vision General Manager and GTB WG-S Chair

GTB Working Group Strategy was founded in April 2017 to advise the GTB General Assembly and Technical Steering Committee on GTB process improvements, new topics for study and their priority and to define the pre-conditions for the scientific basis of proposals for new regulations.

University	Study	Road projection Front	Road projection rear	AV Information display front	Next step
GT (D)	1.1 Driving through Construction Zones	x			Informal proposal planned for GRE in October 2019 (WG-FL)
GT (D)	1.2 Overtaking: Optical Safety Zone (OSZ)	x			
TUD (D)	1.3 Projection of symbols as information for driver	x			
ELS (F)	2.1 Parking / Deparking indication	o	x		
TUD (D)	3.1 Cultural aspects in understanding of used symbols in Car to Pedestrian Communication			x	<ul style="list-style-type: none"> <li>Investigation about signal definition</li> <li>Interaction between several AV cars and Pedestrians</li> </ul>

It is a special group in GTB because it operates with a Chair and two Vice-Chairs and currently has 26 company members represented by CTO's, VP's, and General Managers. All the member companies agree to pay a fee to sponsor independent university studies. There is a good participation (~80%) at each meeting.

Wolfgang Huhn reviewed nine research projects that are being funded by GTB, some already completed and presented to GRE. He also presented a list of future items to study as part of the GTB roadmap 2020-2030.

### 3.9 Interviews: the great heritage

#### **Wolfgang Huhn:**

**DVN : Could you present the main steps of your wonderful career?**

**Wolfgang Huhn :** Nobody could imagine in the late 80s, when I started in the industry, where the vehicle lighting technology stands 2020. I was involved in more or less all lighting innovations of the last 33 years. I could leave my footprint in many of this new products and functions. This was a fantastic time. Also supporting younger people, helping to start a career and/or support to create innovations was really satisfying.

**DVN : What are the main achievement you are proud of?**

**Wolfgang Huhn :** I am proud that I could contribute to change automotive lighting from a commodity to an important, high tech brand shaping element. The whole industry has changed and I was a part of this revolution.

**DVN : What are your main skills which help you in your career?**

**Wolfgang Huhn :** In my whole professional life I had the great luck to have good mentors and some important skills at the right time. This was lighting knowledge and the ability to bring the right people together. To create an innovation you basically and essentially need a close daily contact with the designers and fast decisions by the top management. You are unstoppable if you can achieve this. I had this great but demanding environment over years.

The international lighting network is very remarkable. Some guys, I had professional contacts with, became friends over the years. In Europe, in Asia and America. All the people I have met in the car lighting business talk respectful and friendly with each other, including strong competitors. I always loved to be a part of this great community

**DVN : Do you have a regret in your lighting career?**

**Wolfgang Huhn :** I was not able to bring the right people together in absolutely every case.

**DVN: Few weeks before leaving your second family, and mainly your so involved team, what is your feeling?**

**Wolfgang Huhn :** Of course I am somewhat sad. 20 years with Audi will end now. But by far the worst is to cancel the farewell party, as well as the Christmas party, because of Covid. To understand how big the disappointment is for me, you must know that the Audi lighting team has had legendary Christmas parties.

I want to say thank you to my co workers and the whole development-, design- and purchase-teams who made everything possible.

**DVN : And now, what do you see the future of you career?**

**Wolfgang Huhn :** I will continue to be a part of the international lighting family as member of DVN and GTB! ☺

#### **Stephan Berlitz: From the heritage to the future – November 2020**

**DVN: First off, congratulations! You have now the seat of Wolfgang Huhn who has, with your help, made wonderful achievements over decades at Audi. How are you feeling about it all?**

**Stephan Berlitz:** Thank you. Actually I had a lot of different thoughts and feelings in my mind, but mainly I have been very happy to get the chance to continue working on Audi lighting and to work together with this great team. The positive chances and possibilities are predominating my feelings for this new job.

**DVN: Could you introduce yourself, education, career, and family?**

**Stephan Berlitz:** My first contact with lighting was actually already during my electrical engineering studies at the Technical University of Munich. I worked from 1987 to 1989 as a working student for light measurement in a research institute. From 1989 I worked as a working student in the BMW light tunnel and was operating the new photogoniometer. The lighting engineer who employed me was Wolfgang Huhn. In 1993 I finished my studies with the diploma thesis on "variable light distributions for automotive". In 1994 I started at Reitter & Schefenacker, now known as Odelo, as a tail light developer. Working for a supplier all around the world as project leader, resident engineer, and finally program manager was a highly informative experience. In 2001 Wolfgang asked me to follow him to Audi and to take over the job of developing lighting innovations there. And then we had two really successful decades together, bringing really game changing innovations to market, like LED DRL, LED front lights, matrix light, dynamic direction indicator, laser lights, OLED, digital matrix light and many more fascinating lighting ideas.

Outside the job, my family is the perfect surrounding to rest my mind. My wonderful wife—by the way we live together even longer than I know Wolfgang—manages our family with heartiness. We have four children, one son and three daughters, all studying except the youngest; she will finish school next year. Therefore, there is plenty of distraction and fun and revitalisation.

**DVN: What were your first reactions after your nomination?**

**Stephan Berlitz:** I was really thrilled, and in the evening my wife and I clinked glasses. Since then there have been a lot of discussions and decisions, and also a lot of pleasure with my new responsibility.

**DVN: You were been working with Wolfgang for around two decades. What do you retain on relationship and achievements?**

**Stephan Berlitz:** Two decades at Audi and more than one decade before. We have quite the same mindset about values and respect, and Wolfgang was always supporting my innovation ideas. He pushed innovations personally, also with his unbelievable network inside and outside Audi. We had plenty of successful projects, lots of fun while working and while celebrating successes. In addition, Wolfgang lives for lighting and I am more than thankful that he will continue developing our lighting community within GTB and DVN.

**DVN: Have you already in mind some targets for the future in your new position?**

**Stephan Berlitz:** There are a lot of changes within the automotive industry, within the Volkswagen group and within Audi. My main target is to optimise our small lighting department into a more functionally orientated organisation, so that we can realise our innovation roadmap.

My team really burns for lighting and together with my well-known colleagues Michael Hamm and Michael Kruppa we will develop fascinating front and rear lamps. Within Audi my colleague Konrad Schneider supports me with a very efficient project management team and last but not least Cesar Muntada and his lighting designers are unbelievable creative, You can look forward to surprising new Audi lights.

## 4. ADAS at Audi

### Audi ADAS R&D office opens in Silicon Valley

Audi have opened their new Audi Automated Driving Development (A2D2) R&D office in San Jose, California, to create ADAS specifically for the US market. Located in the heart of Silicon Valley, A2D2 will have the flexibility to quickly develop new software and to collaborate with nearby startups for production-intent applications.

The U.S. is expected to continue its lead in terms of ADAS system capabilities based on artificial intelligence and its cloud supported development processes in the push to more advanced Level 2+ automated systems for the coming decade worldwide.

While Audi maintain R&D offices in various locations throughout the U.S., A2D2 is the first office dedicated to developing ADAS hardware and software specifically for US roads and driving behaviours.

### 4.1 Frontal ADAS functions used by Audi

#### Intelligent Headlamps

LED matrix head lamps can preferentially illuminate specific areas of the front field (roadside, curve's entry, signs) and avoid to dazzle other vehicles (cruising especially moving in the opposite direction). The front camera ensures detection of these vehicles to address in real time an adequate mapping of illumination towards the lighting system.

#### Night Vision

Night vision cameras working in the far infrared spectrum (8 to 14  $\mu\text{m}$ ) allow to perceive pedestrians and animals to help the driver in night conditions. Restitution of the front thermal image is done on a part of the dashboard screen.

#### Pre-Sense Front at Audi

The new 3020 regulations or NCAP criteria on Automated Emergency Braking make active safety functions now mandatory on each new vehicle to augment passive safety functions. Consequently, Audi sell this function on all their vehicles, from e-Tron and A1 to Q8 cars. Depending on the vehicle's segment, Pre-Sense Front uses a front radar or a multifunction camera, or a set of two midrange corner radars to detect the road space in front of the vehicle. Pedestrian and cyclist are also detectable. In case of a collision risk with them or other vehicles, the system will alert the driver with visual and audible signals. If the driver does not react, the system will trigger a brief brake tap as a warning. If still no reaction by the driver, the seatbelts are pretensioned before the car does full automatic braking.

#### Pre-Sense Basic

This passive safety function provides automatic safety belts tightening in case of unstable driving or imminent collision. Depending on the scenario, the windows can also close, or hazard lights can be activated to alert traffic coming from behind. This functionality can be optionally added to Pre-Sense Front.

## **Cross Assist**

This system allows to detect as early as possible vehicles coming from the right or the left at a junction, or to recognise a pedestrian crossing the street in a right-turn (in RH-traffic countries) scenario. This functionality is ensured by a set of two 77GHz mid-range corner radars on A7, A8, Q7, and Q8 vehicles.

## **Traffic sign recognition (TSR)**

This application is embedded in the multifunction camera to recognise traffic signs and particularly, speed limits, stop signs. It is proposed as a standalone function with a displaying of detected signs on the dashboard display. It can be associated also with functions like ACC or AAD. Embedded navigation data base can help the function to know more surely speed limits or other landmarks.

## **Adaptive Cruise Control at Audi**

This function is sold currently, as an option, on a wide spectrum of Audi vehicles from A3 to A8 and from Q3 to Q8. This longitudinal control is proposed on different level of performance:

- As a simple ACC working from 30 km/h to a limited speed in manual-transmission vehicles
- A full speed range ACC + Stop & Go working from 0 to the maximum speed
- A high-end ACC + Stop & Go (Adaptive Automated Driving) coping with a trajectory following control referenced to a local mapping of vehicles, lanes marks and road borders. This local map named "occupancy grid" defines the limits of the driving space where a trajectory can be chosen, taking in account road rules, vehicle's limits and driver's demand. It is acquired through the use of high-resolution sensors like a lidar, a multipurpose front camera, and/or an onboard high definition map.

ACC function has been provided since 2003 by Audi, firstly on the higher segment vehicles (A8). This ACC was based on a front long-range radar working in the 77GHz band. This function is designed to maintain a chosen velocity and a chosen headway between the vehicle and the closest vehicle ahead, in the ego lane. ACC systems with Stop&go features, using 77GHz corner radars, can ensure more safely complete stops and accelerations back behind another vehicle in traffic jam conditions.

This L<sup>1</sup> AD system generates an alert to the driver when functional limits are overtaken, for example, when the deceleration capability of ACC is overtaken ( $3 \text{ m/s}^2$ ) in regard with the necessary deceleration.

## **Adaptive Automated Driving**

This optional L<sup>2</sup> AD function uses both a full range speed ACC and a trajectory-following assistant. The main functionalities of this function are:

- Improved driving comfort on long journeys
- Calculating an ideal virtual trajectory for the vehicle, accounting for road configuration and vehicles
- Maintaining a set speed; the system reacts to vehicles ahead by keeping a safe distance.
- Intervening on the steering system to keep the vehicle in the centre of its lane of traffic. The system detects ground markings, side lanes, vehicles travelling in parallel lanes, and several vehicles ahead
- Adapting speed on narrow taxiways to allow for staggered driving, for example in case of road work areas.

A Front scanning Lidar, Front Corner radars, Rear corner radars and the front camera are fused by Audi to ensure a redundant perception of the environment and a better-backed decision process.

A specific Emergency Braking assistant complete the function in case of system's limits or failures:

- It recognises when the driver is inactive and warns them with a visual, acoustic, and haptic warning
- If the driver has no reaction, it takes support for the direction and automatic braking of the vehicle up to a complete stop in its own lane
- Simultaneously activates Audi pre-sense protection measures to enable the rescue of passengers
- If necessary, an automatic emergency call is sent to the Audi cloud

## **Traffic Jam Pilot at Audi**

This system, using Scala lidar from Valeo, was the most significant technological breakthrough added to the latest A8. At that time Audi said the system would only be activated in markets where governments allowed it. Since then, global regulators in Geneva have still not agreed on a type approval process for even the most rudimentary L<sup>3</sup> functionality. At that level a vehicle can be put in autopilot mode under certain circumstances, allowing the driver to take eyes off the road.

Given the various regulatory delays, Audi say they won't have sufficient time to make their L<sup>3</sup> system compliant in the newest A8 by the time it launches on the market.

## **4.2 Rear & Side ADAS functions used by Audi**

### **Lane Departure Warning (LDW)**

The lane departure warning helps to prevent the vehicle from unintentionally straying out of its lane. If the system is activated and ready for use but the driver has not turned on the blinker, the system corrects the direction to prevent the vehicle crossing the detected demarcation lines of the lane. An additional steering wheel vibration is also adjustable as desired by the driver. The line detection task is handled by the front multipurpose camera, and operating range of LDW is from about 60 km/h up to 250 km/h.

### **Lane Keeping System (LKS)**

Lane Keeping is a precise control of vehicle's position between the lines of a single lane. This system acts automatically on the steering system when it is engaged by the driver or when a more transversal function like AAD is working. The line detection task is handled here, too, by the front multipurpose camera.

### **Side assist at Audi**

Lane Change Assist, called "Side Assist" by Audi, is active from approximately 30 km/h and monitors the side areas (left and right) behind the vehicle during cruising. It informs the driver by a signal in the outside rearview mirror as soon as the system detects a vehicle in the blind spot or approaching from the rear with a minimum Time To Contact (about less than 3.5s) at less than 70m. Two rear corner radars are integrated behind the rear bumper to cover two different zones: the blind spot area from 0 to 3m behind the vehicle (BSD), and the Lane change area from 3m to more than 70m behind the vehicle (LCA). On A7, Q7 and Q8, BSD detection is standard but LCA is optional. For these cars BSD is covered by ultrasonics by default. If LCA is chosen, a rear radar will be used to cover these two domains. The detection of incoming vehicles in the rear is assumed by a set of two rear corner radars integrated behind the rear bumper. Originally (2003-2005 models) these radars were designed in a 24 GHz narrow-band technology.

### **Active Side Assist**

Active Side Assist is active from approximately 30 km/h and monitors the side areas (left and right) behind the vehicle during cruising and informs the driver by a signal in the outside rearview mirror as soon as the system detects a vehicle in the blind spot or approaching from the rear with a minimum Time To Contact (about less than 3.5s). In such conditions, the function reacts on the steering wheel to avoid any lane change of the vehicle during this situation. The detection of incoming vehicles in the rear is assumed by the two rear corner radars.

## 4.3 ADAS for Low Speed Manœuvres used by Audi

### Rear Cross Traffic Assist (RTCA)

In parkades and lots, drivers usually enter a parking place nose-first. When the vehicle has to leave this place, the driver's view of vehicles circulating in the driveway can be blocked, making the reverse manœuvre hazardous. The set of two rear corner radars and possibly the rear camera can offer a better preview of the driveway. This function, named Rear Cross Traffic Assist, is proposed optionally in complement of other rear functions.

### Rear Parking System

The Audi parking system at the rear facilitates parking and reverse manœuvres using an audible signal indicating the distance from an identified rear obstacle. The measurement is done by a set of 6 ultrasonic sensors discreetly integrated into the bumper fascia, that are activated by the reversing lamp circuit (which goes live as soon as reverse is engaged).

### Parking System Plus

This function uses the set of 12 ultrasonic parking sensors (front and rear) and adds in the rear camera to offer a view of rear conditions to the driver and to suggest him the possible rear trajectory in respect with obstacles, on a dedicated screen. On A5, A8, Q7, and Q8 this rear camera is completed by three body cameras to provide a panoramic view—one in the front grille and the two side mirrors bases. These four body cameras can offer a bird's-eye (overhead) view of the car and parking space for the driver's ease of entry and exit.

### Park Assist

This function looks for appropriate parking spaces along the roadway using lateral ultrasonic sensors and assists the driver with autonomous manœuvres to get in and out of parking spaces. The driver simply accelerates, brakes and monitors progress. The steering angle is controlled by the system. The parking space will be detected by one of the front side ultrasonic sensors when the vehicle drives below 10 km/h looking for a parking space. After detection is announced, to accept the space the driver stops and activates the automatic manœuvres.

### Park Assist Plus

Park Assist Plus fully takes over control of parking functions, including steering, braking, and accelerator. Currently, the driver must still be aware of the vehicle's surroundings and be willing to take control of it if necessary.

## 4.4 Summary

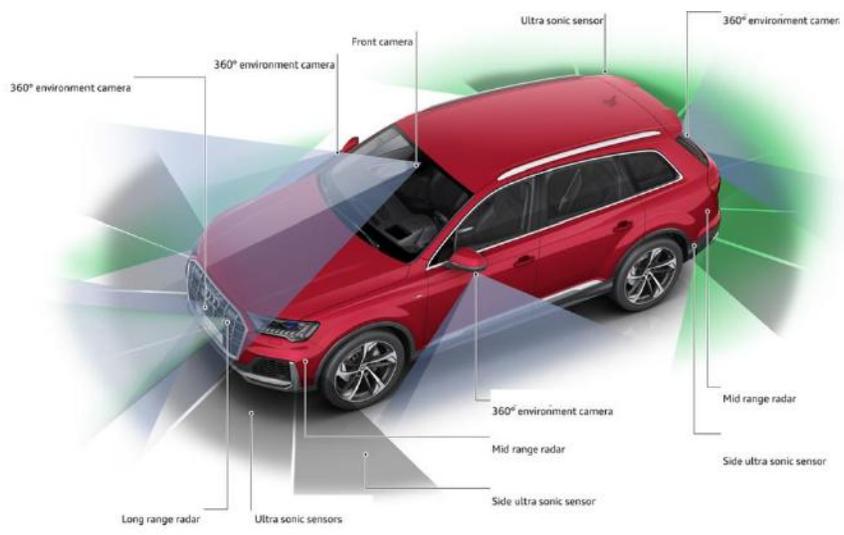
This table summarises the array of ADAS systems used by Audi

"S" = Standard equipment "O" = Optional equipment

Road Assist Package City Assist Package

	e-Tron	A 1	A 3	A 4	A 5	A 6	A 7	A 8	Q 2	Q 3	Q 5	Q 7	Q 8
Night vision							0	0					0
Pre Sense Front	S	S	S	S	S	S	S	S	S	S	S	S	S
Pre Sense City				S	S						S	S	S
Pre Sense Basic	S	0	0		0	0	S	S	0			0	0
Crossing assistance							0	0				0	0
TSR	0		0		0	0	0					S	S
ACC			0		0	0				0			
Adaptive AD (L2-L3)							0	0				0	0
LDW	S		0			0	S			S		S	S
LKS					0	0	0	0				0	0
Side Assist (BSD)			0				0	S	0	S		0	0
Side Assist (LCA)			0				0	S	0			0	0
Active side assist					0	0	0	0				0	0
Pre sense rear	0						0	S	0			0	0
RCTA							0	S	0			0	0
Rear Parking syst.		0	0	S	S	S			S	S	S		
Parking system Plus	S			0	0	0	S	S	0	0		S	S
Park Assist (steer)			0		0		0		0			0	
Park Assist Full								0		0			0

Consequently, the following table can illustrate the sensors equipment depending on vehicles and their options:



***Q7 sensors (with all options)***

## Conclusion



*The management team*

For many years, vehicle lighting was regarded as more or less a commodity, with occasional technical innovations—like wheel nuts or windows, the absence of lights would be noticed, but their presence was taken for granted. Audi's strategic decision to position themselves as lighting leaders has paid handsome dividends for the company and their customers. And for the auto industry as a whole; more than one other maker has, with grudging respect, referred to what they call the "Audi Curse": Audi started putting highly designed and engineered fancy lights on their cars, so now everybody else has to try and keep up.

Clearly, technology and design are inseparable for Audi's lighting team. They work coordinated magic to choreograph light inside and outside the car to escort the driver and passengers safely, comfortably, and delightfully in a visual expression of "Vorsprung durch Technik", Audi's motto ("progress through technology"). Night or day and near or far, an Audi is instantly recognisable at a glance, by dint of its lights.

It's not a passing fad; Audi's lighting carries on going from strength to strength because top executive managers are involved in lighting—a unique strategy for an automaker. And Audi lighting engineers and designers participate actively and enthusiastically in the lighting community, presenting their innovations for safety and style: LED DRLs, dynamic turn signals, matrix beams, laser boosters, OLED tail lights, full width rear lights, high-definition lighting, welcome/farewell dancing-light shows, customisable pixellated signature lighting, and we're quite sure we're nowhere near the end of the list..

The strategic and innovative fruits of Audi's lighting efforts are well summarised by outgoing Lighting and General Vision Manager Wolfgang Huhn, and incoming one Stephan Berlitz:

**Wolfgang Huhn:** "Nobody could imagine in the late 1980s, where vehicle lighting technology would stand in 2020. Audi were involved in more or less all lighting innovations."

**Stephan Berlitz:** "The team really burns for lighting and together with my well-known colleagues Michael Hamm and Michael Kruppa we will develop fascinating front and rear lamps. Within Audi my colleague Konrad Schneider supports me with a very efficient project management team, and Cesar Muntada and his lighting designers are unbelievably creative. You can look forward to surprising new Audi lights".

We can't wait to see what Audi's lighting wizards come up with next!

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 FCA, USA  
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 NAL, USA  
 Neolite ZKW, India  
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 Odelo, Germany  
 Phoenix Lamps, India  
 Plastic Omnium, France  
 Peterson, USA  
 Rebo Lighting, China,  
 Germany  
 SL Corporation, Korea  
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 China  
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 Osram, Germany  
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 DEKRA laboratory, Nederland  
 FEP, Franhauser, Germany  
 Fudan university, China  
 GranStudio, Italy  
 Hannover Leibniz Univ.(HOT),  
 Germ.  
 Institut d'Optique, Fr.  
 Karlsruhe Lighting Institute,  
 Germany  
 LAB, France  
 Light Sight Safety, Belgium  
 Nuremberg university, Germany  
 Pacific Insight, USA  
 Parma university, Italy  
 Rensselaer university, USA  
 SLD Laser—formerly Soraalaser  
 UMTRI, USA  
 University of California, Santa  
 Barbara  
 YoungNam University, South  
 Korea  
 Mr Shunxing Wang, China

## Lighting Suppliers

3M, USA  
 A2Mac1, France  
 AML Systems, France  
 ANSYS, Europe  
 Aspöck Systems, Germany  
 ASYST Technologies, USA  
 Auer-Lighting, Germany  
 Bicomoptics, China  
 Bühler Alzenau, Germany  
 Covestro, US, China, Europe  
 Dajac, USA  
 DBM Reflex, Canada  
 Delvis, Germany  
 DesignLED, UK  
 Docter Optics, Germany  
 EcoGlass, Czech Republic  
 Elmos, Germany  
 Enmech-Mektec, Germany  
 GXC Coatings, Germany  
 Holophane, France  
 IMS, Netherland  
 Infineon, Germany  
 Inova Semiconductors, Germany  
 Instrument Systems, Germany  
 Jenoptik, Germany  
 Keboda, China  
 Less, Switzerland  
 Lightworks, Germany  
 LMT, Germany, China  
 Luminet, USA  
 Luminus, USA  
 Lumitex, USA  
 Maxell Joei Tech, Japan  
 Mentor Graphics, Europe, USA  
 Mitsubishi Electric, Germany, Jap.  
 Myotek Industries, USA  
 Nalux, Japan  
 NXP, UK  
 ON Semiconductor, Europe, Asia  
 Optoflux, Germany  
 Panasonic, Japan  
 Proper Group, USA  
 Red Spot, USA  
 Sabic, USA  
 Sapphire, USA  
 Sea Link International, USA  
 SUSS MicroOptics, Switzerland  
 Synopsys, USA, Germany  
 TechnoTeam, Germany  
 Texas Instruments, USA  
 TQ Technology, Taiwan  
 Weidplas CH, Switzerland  
 WL Gore, USA  
 Zollner, Germany

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LEDs Thermo-Electrics  
Interior Lighting  
BMW and lighting  
Lighting and Driver Assistance  
OLED technology  
Materials in lighting  
Laser Headlighting  
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ADAS and Lighting  
India Car Industry and Lighting Market  
Advanced Motorcycle Lighting  
Peterson Manufacturing  
NAIAS Auto Show  
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Geneva Auto Show 2016  
Vision of lighting 2025-2030  
DVN Tokyo workshop  
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New ADB technologies  
Mondial Paris Auto Show  
VISION Congress Vehicle Lighting in USA  
NAIAS Auto Show  
Delhi Auto Expo 2016  
Vision of lighting 2025-2030  
DVN Tokyo workshop  
Vehicle lighting Regulations worldwide  
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VISION Congress Vehicle Lighting in USA

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Interior Lighting  
Israeli Startups  
ISAL symposium  
Jaguar Land Rover and Lighting

## 2018 Reports

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Engineering companies in lighting  
Japanese lighting market  
DVN Tokyo Workshop  
Camera technologies  
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Mondial Paris Auto Show  
Vision congress  
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Shanghai Auto Show  
Materials in vehicle lighting  
Status of Regulations  
Integration of ADAS in Lights  
IAA Frankfurt Auto Show  
ISAL  
Vehicle lighting in America  
Interior lighting

## 2020 Reports

21 January - CES,  
11 February - DVN Munich workshop  
17 March - Geneva autoshow  
22 April - US automotive lighting industry  
9 June - Marelli profile  
30 June - 50 years LightStyling  
21 July - ADAS and Lighting  
29 September- Evolution of LED  
27 October - New worldwide models  
15 December – Audi profile

## About the authors and Driving Vision News

**Jean-Paul Ravier** joined Valeo in 1972, then Valeo Lighting in 1984. Since that time and until his retirement in 2013, he had a variety of responsibilities in the technical organisation including projects, R&D, and advanced technology. Since 2014, he is at the head of the ELS (Embedded Lighting Systems) chair for advanced training and research in lighting, a joint educational program of the Institut d'optique graduate school, ESTACA, and Strate Design School, with the support of the founding partners Renault group, PSA group, Automotive Lighting, and Valeo and the associate partners Osram, Mentor Graphics and Bertrandt. Since his retirement, he works for Driving Vision News

**Hector Fratty's** entire career has been in vehicle lighting. From 1995 to 2006, he was Valeo Lighting Systems' chief of R&D and now presides over the biennial VISION Congress international vehicle lighting and driver assistance symposium. He is also a member of the steering committee which administers ISAL, the International Symposium on Automotive Lighting organised by TU Darmstadt. He is founder and president of Driving Vision News.

**Daniel Stern** is DVN's Chief Editor based in Vancouver, BC, Canada. He is considered by DVN President Hector Fratty as one of the five greatest lighting experts in North America. He is an appointed member of the US transportation Research Board Visibility Committee, which steers North America research on matters related to automotive conspicuity, lighting performance and regulation. He is an active member of the SAE Lighting Systems Group, and attends and participates in the world's automotive symposia and technical conferences.

### Driving Vision News

DVN is the vehicle lighting and ADAS industry's journal of record, dedicated to keeping the community informed and communicating about the latest progress and developments. DVN's three pillars are

- **Technological watch** on new emerging technologies, with weekly electronic newsletters bringing news, analysis, and crucial information on innovation in lighting, ADAS, and smart car interiors; there are also monthly technical reports with sharp focus on cutting edge technologies, company profiles, regulatory matters, and other relevant content available only from DVN
- **Networking** of high-level decisionmakers, researchers, innovators, practitioners, academics, and regulators to make new business connections with two workshops per year in rotating locations throughout America, Europe, China, Japan, India, and Korea. DVN Workshops gather over 300 participants.
- **Promotion of innovations** from DVN's 150 member companies—we facilitate the promulgation of knowledge of innovation, which in turn paves the way for commercialisation, enabling to build new relationships through DVN Community to forge new business worldwide. The DVN Gold membership roster includes 30 automakers, 30 lighting & ADAS tier-1 suppliers, 15 light source suppliers, 50 tier-2 & -3 suppliers, and a wide variety of universities, research outfits, and consultants. DVN Gold members receive all publications and attendance privileges at all DVN Workshops. Basic members—2,500 and counting—receive Newsletters and can obtain access to other DVN publications and functions.