Maximizing 5G performance through material solutions

UL Webinar
October 8, 2020

Agenda

1. **Introductions**
2. **The growth in 5G and its implications**
3. **Maximizing mmWave signal transmission**
4. **Beating the heat with thermally conductive solutions**
5. **Q&A**

Covestro – leading in the world of plastics

- €12.4 bn in sales
- 17,200 employees[1]
- Listed on the DAX stock exchange

Global player
- 33 production sites globally
- Close to markets, customers and suppliers

Large portfolio
- Products and solutions for many industries

Highly innovative
- 1,200 employees in research and development
- 80 years of ideas and inventions

Financial year 2019
[1]calculated as full-time equivalent (FTE)

Polycarbonates

Global Footprint to Support our Customers

Global network of Production Sites, Color Competence Centers and Innovation Centers

- Resin Production
- Compounding and Color Competence Center
- Regional HQ / Technical Center

Meet the Covestro Electronics team!

Introduction

Joel Matsco
Senior Marketing Manager

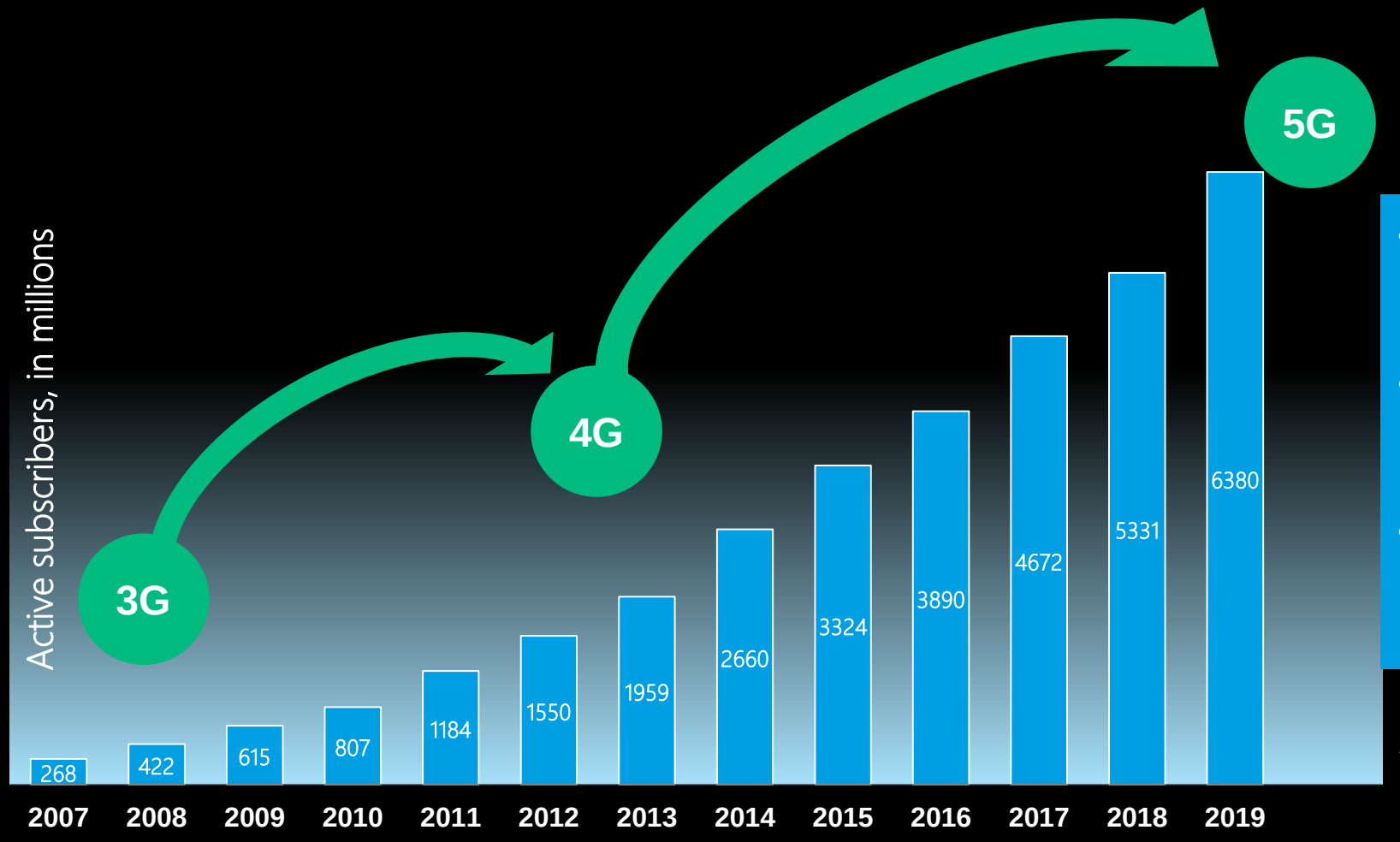
Mark Bondi
Senior Application Engineer

Nick Sunderland
Senior Principal Scientist

The rise of 5G and its implications

Our world becoming ever more mobile (more wireless)

Number of active mobile broadband subscriptions worldwide (2007-2019)

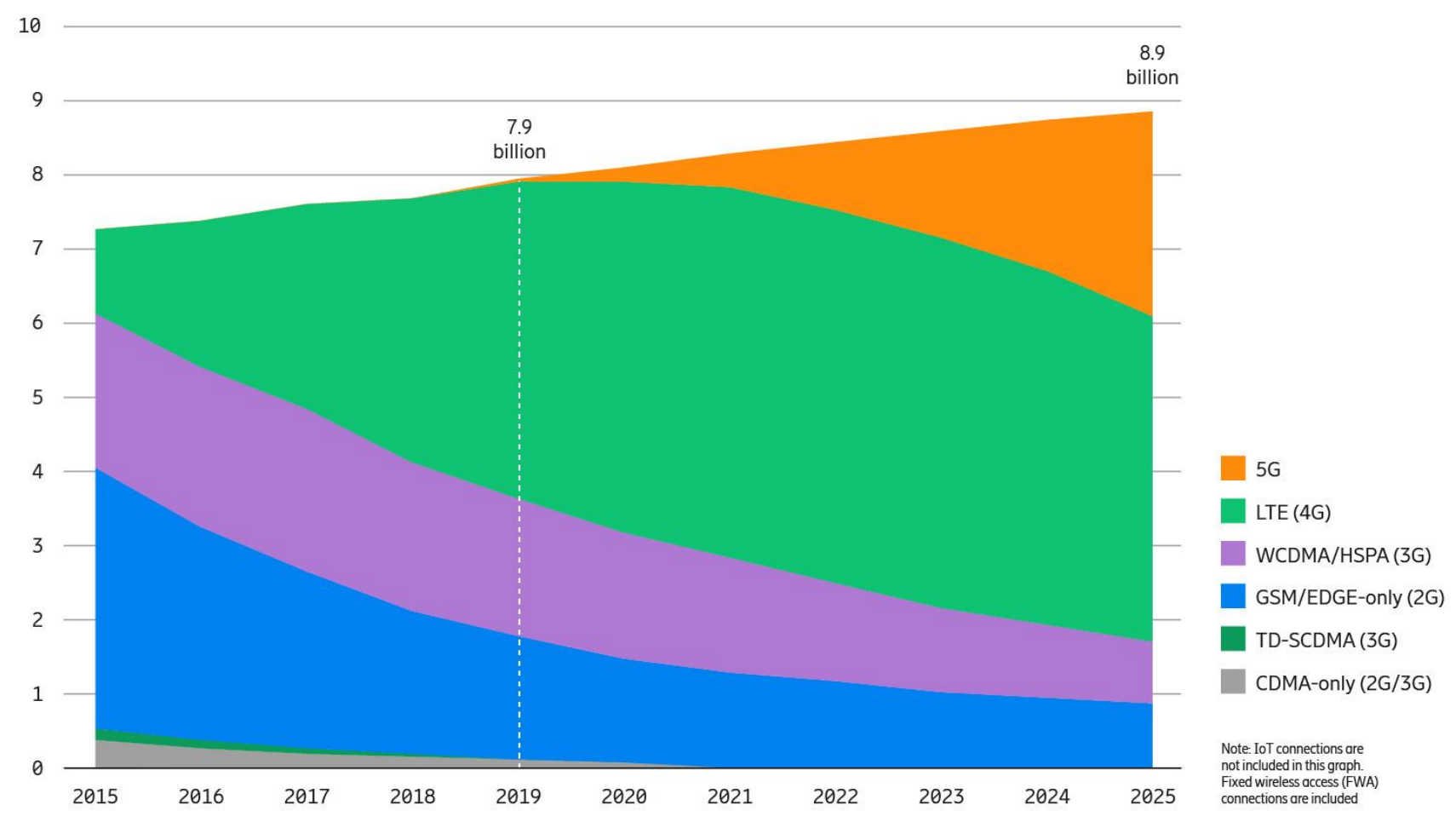


- Mobile users surpassed desktop users in 2014
- Mobile users increasing by CAGR of 8.3% through 2023
- 88% of subscriptions will be mobile broadband by 2025

Source: Statista

5G subscription uptake beginning and *accelerating*

Mobile subscriptions by technology (billions)



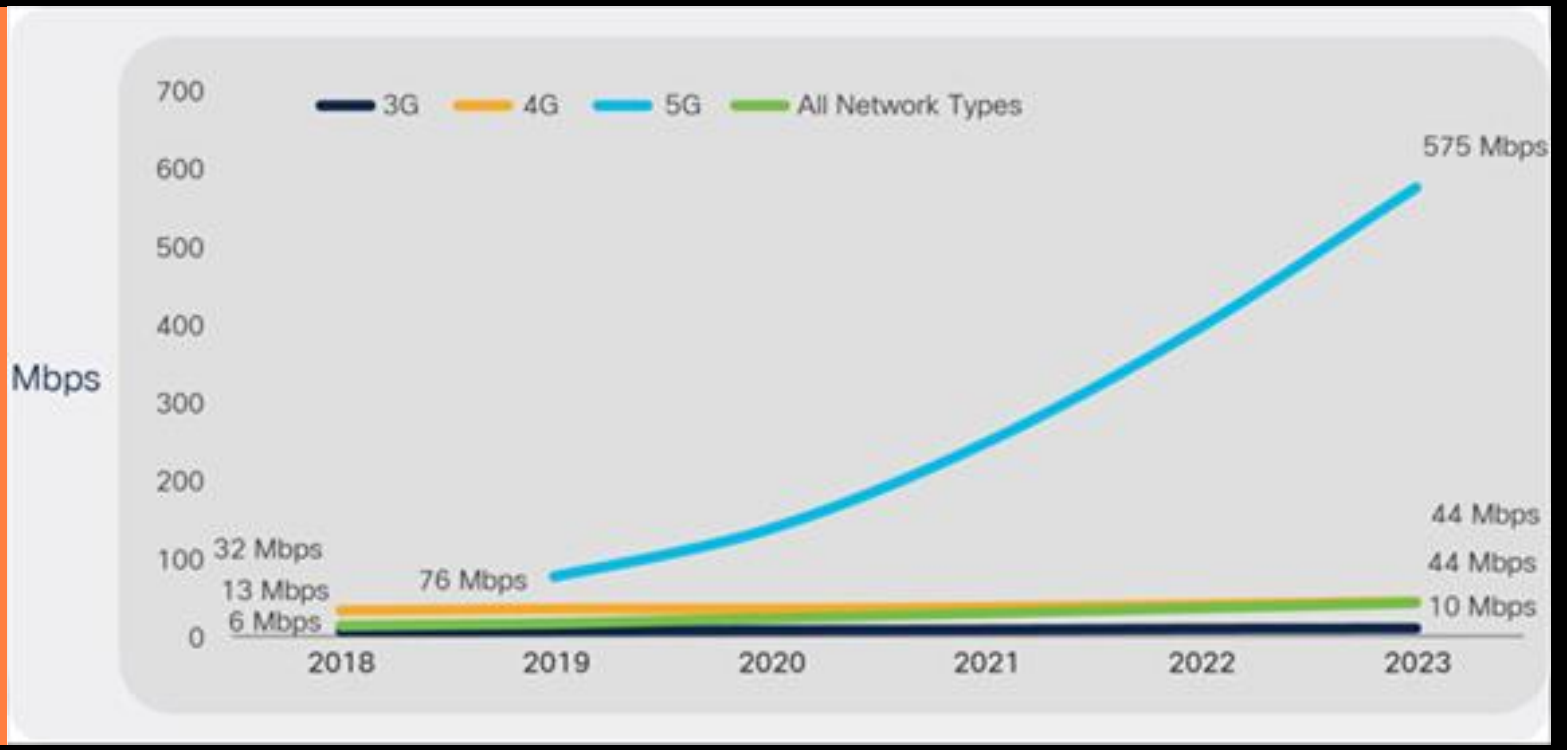
- 2.8 billion 5G subscriptions forecasted in 2025
- 5G uptake expected to be faster than 4G (reaching 1 billion subscribers almost 2 years faster)
- Over 70 percent of the global population will have mobile connectivity by 2023. (71% in 2023 versus 66% in 2018)

Source: https://www.ericsson.com/en/mobility-report/reports/june-2020/mobile-subscriptions-outlook

High expectation for increased mobile speed with 5G adoption

Global mobile average speeds by network type

- Mobile (cellular) speeds will more than triple by 2023.
- The average mobile network connection speed was 13.2 Mbps in 2018 and will be 43.9 Mbps by 2023
- **5G technology enables high speed and low latency**

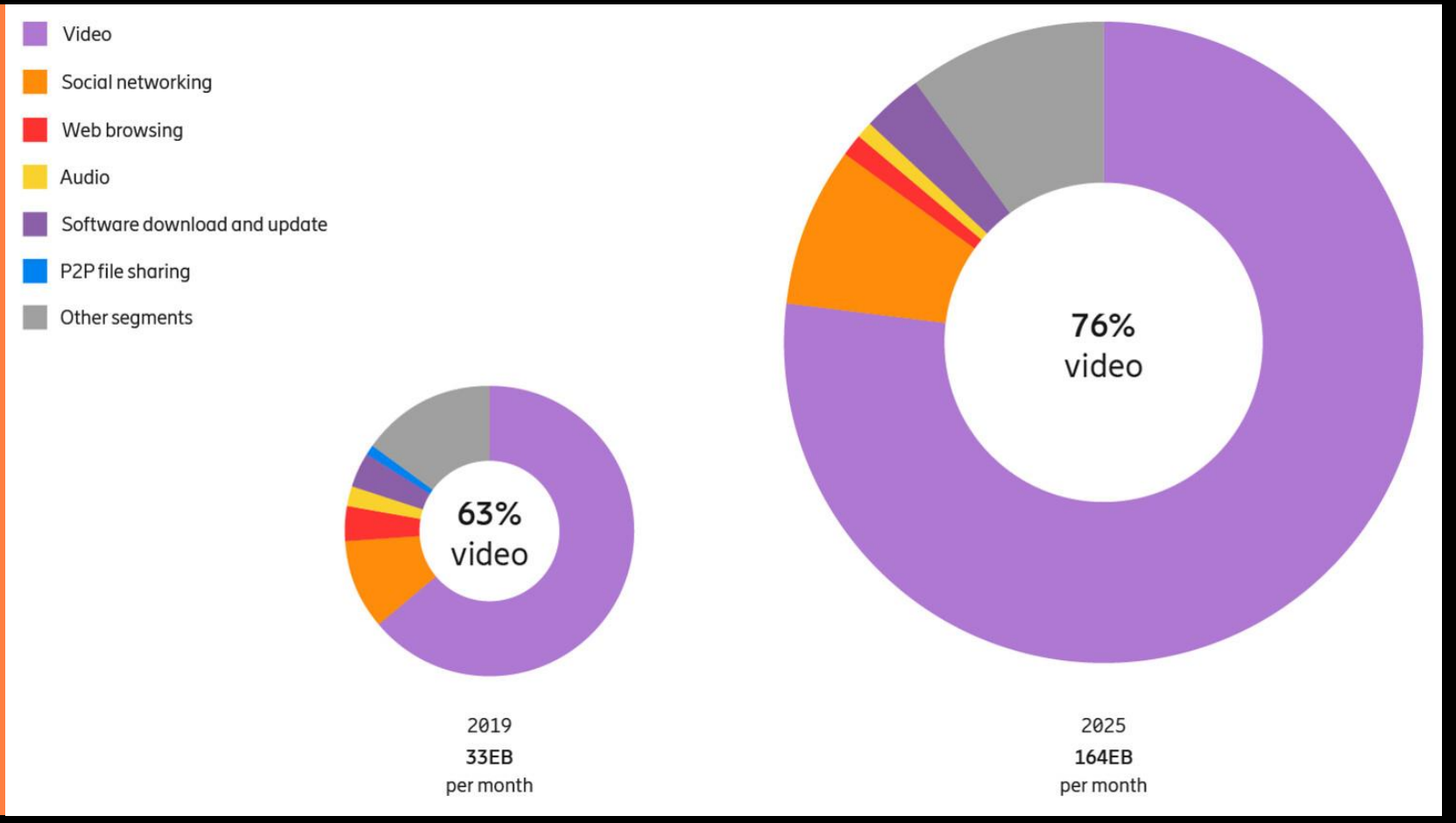


Source: Cisco - Annual Internet Report

Mobile speeds likewise increasing rapidly

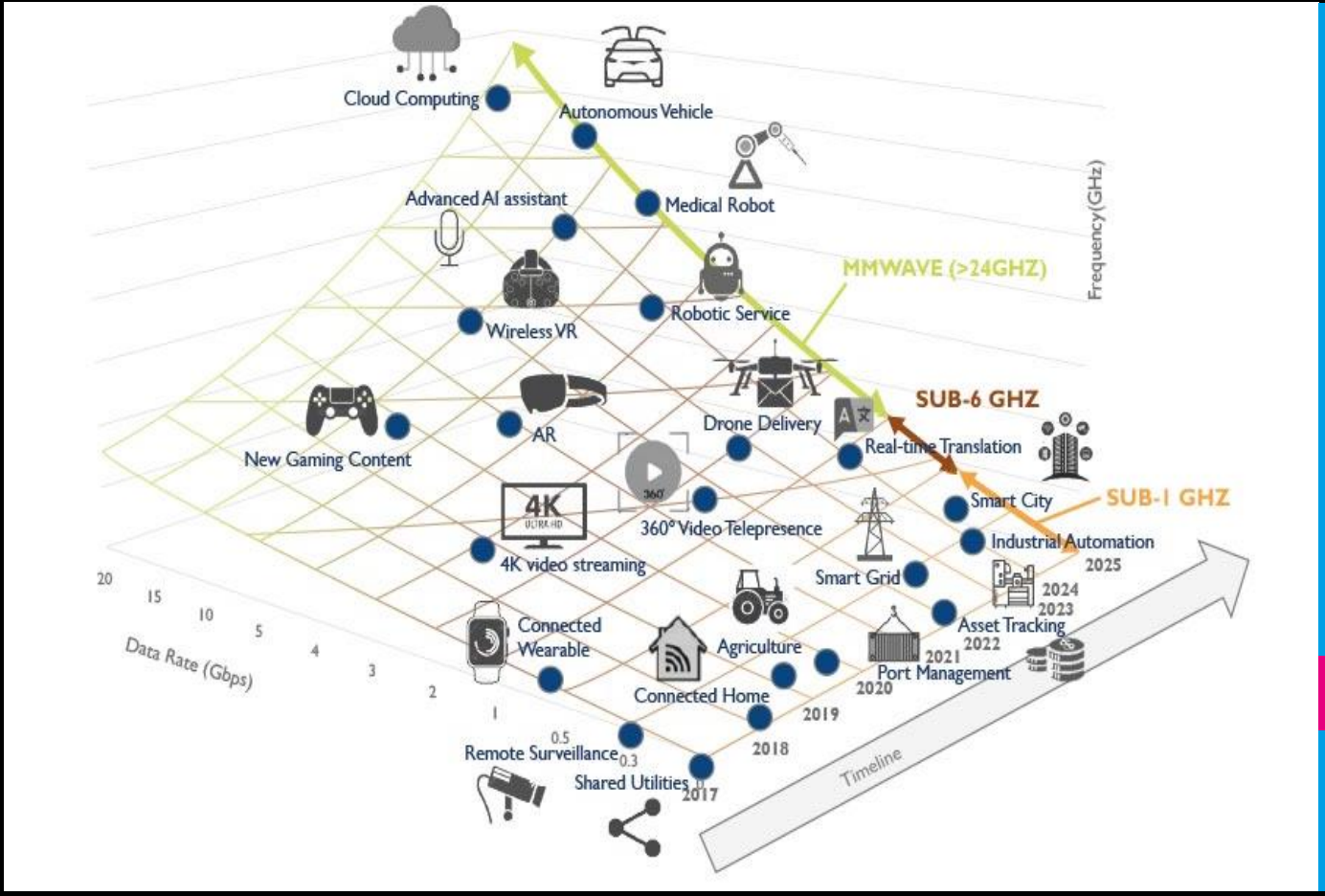
Global data usage (exabytes)

- Video is part of most online content (news, ads, social media, etc.)
- Watching a streamed e-sports event in multi-view would consume about **7GB** per hour, while a high-quality AR/VR stream with a media (bit) rate of 25Mbps would consume as much as **12GB** per hour.



Source: Ericsson - Mobility Report

5G endpoints transitioning from sub-6GHz to mmWave



Fastest (early) growth segments:

- Smartphones (CAGR 7%)
- TV, set-top-box, gaming (CAGR 6%)

- M2M will be half of total device connections:
  - Connected Home (20% CAGR)
  - Connected Work (15% CAGR)
  - Connected Health (19% CAGR)

mmWave adoption limited by line of sight

Source: Cisco Annual Internet Report, 2018–2023

Thermal management to become major performance factor

Opportunity for Thermal Interface Materials

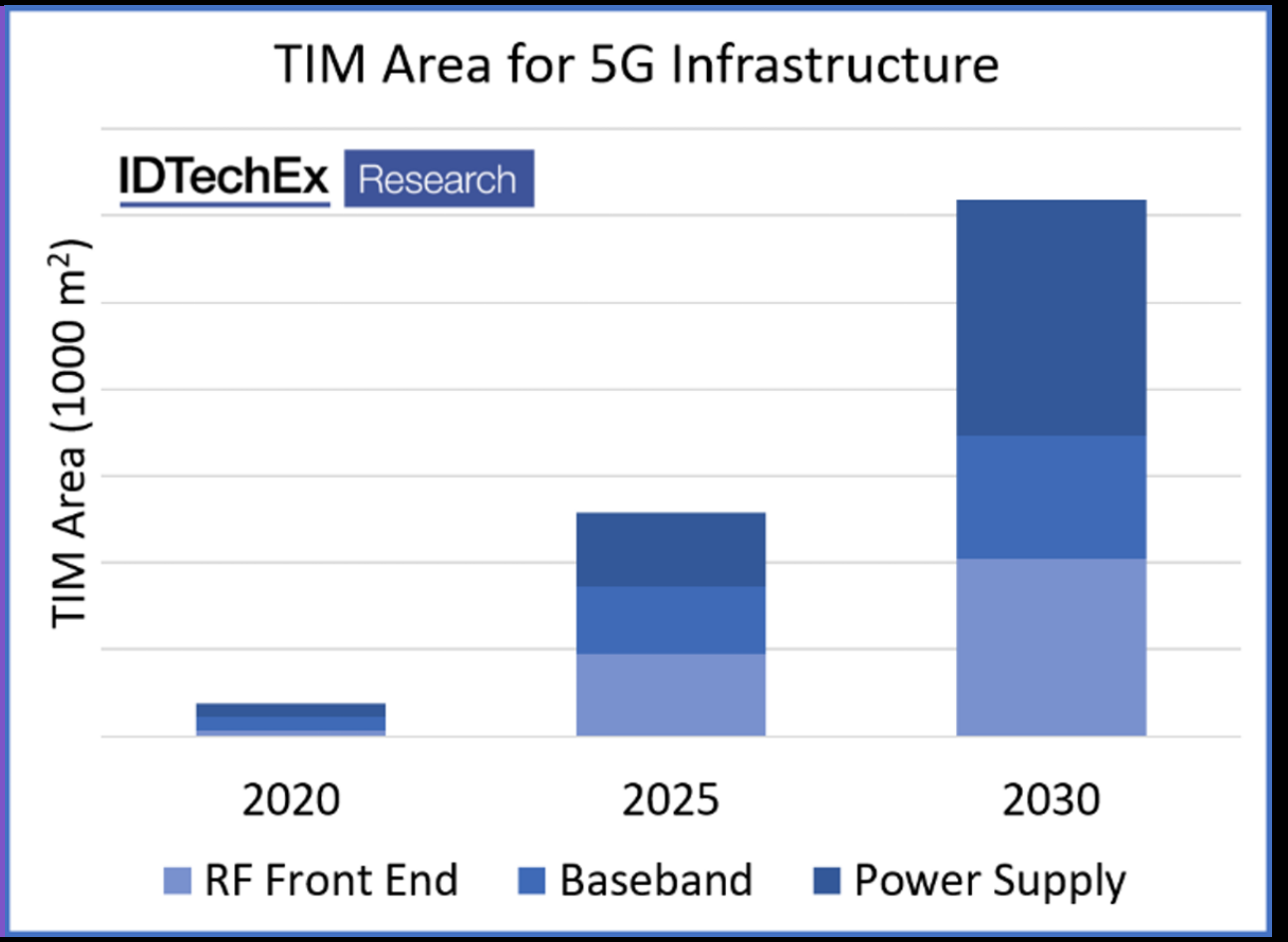
5G implications:

- Higher power baseband processing units
- Higher data transfer rates
- More channels
- Higher total power consumption

Typical LTE basestation today:
Average:6kW 8-9kW at peak traffic

5G in sub-6GHz basestation:
Average: 10.4kW 13.7kW at peak traffic

5G in mmWave basestation:
Average: 13.4kW 18.9kW at peak traffic



RF signal transmission and heat management are key for 5G

Problems to be solved

- 8-10x increase of installations
- Line of sight limitation
- Compact device sizes (small/micro cell)
- Exposure to various environments

Maximize RF transmission in the mmWave bands

Remove heat from power consuming components

Maximizing mmWave signal transmission

Example Network Device

Radome + antenna + heat sink/housing

1K/2K molding housing + heat sink

Makrolon® TC grades

Radome Cover

Material TBD

Needs:

- Toughness
- Predictable signal
- Colorability
- UL-94
- Good flow

Network Device

Radome Cover

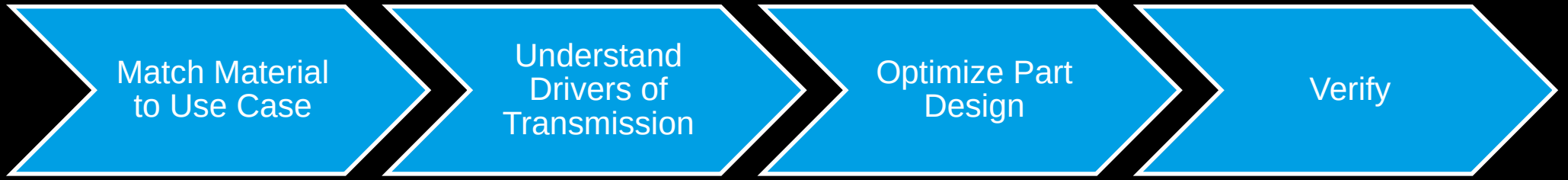
Let’s focus on the radome cover, first

Radome Cover

Material TBD

Part Design Process

Radome Cover



Part Design Process

Radome Cover

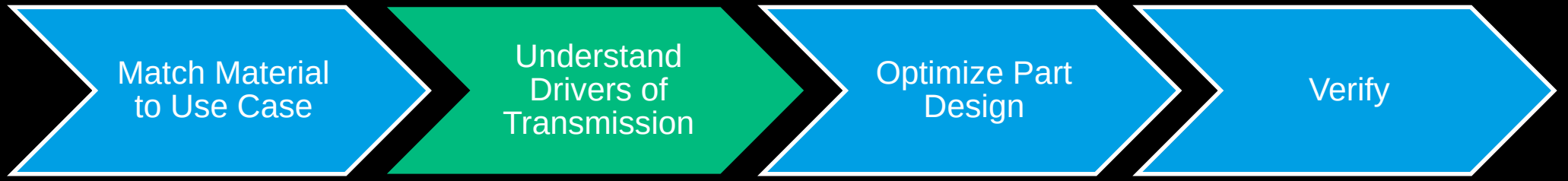
Match Material to Use Case → Understand Drivers of Transmission → Optimize Part Design → Verify

- **UV concerns – inside or outside? F1 rating?**
- **Impact requirements – hail, drop, etc.**
- **Temperature extremes**
- **UL94 Flame Retardancy – V2, V0 at X mm?**
- **Flow – can I fill my part?**

If you can't make the part work, designing for transmission is non-productive!

Part Design Process

Radome Cover



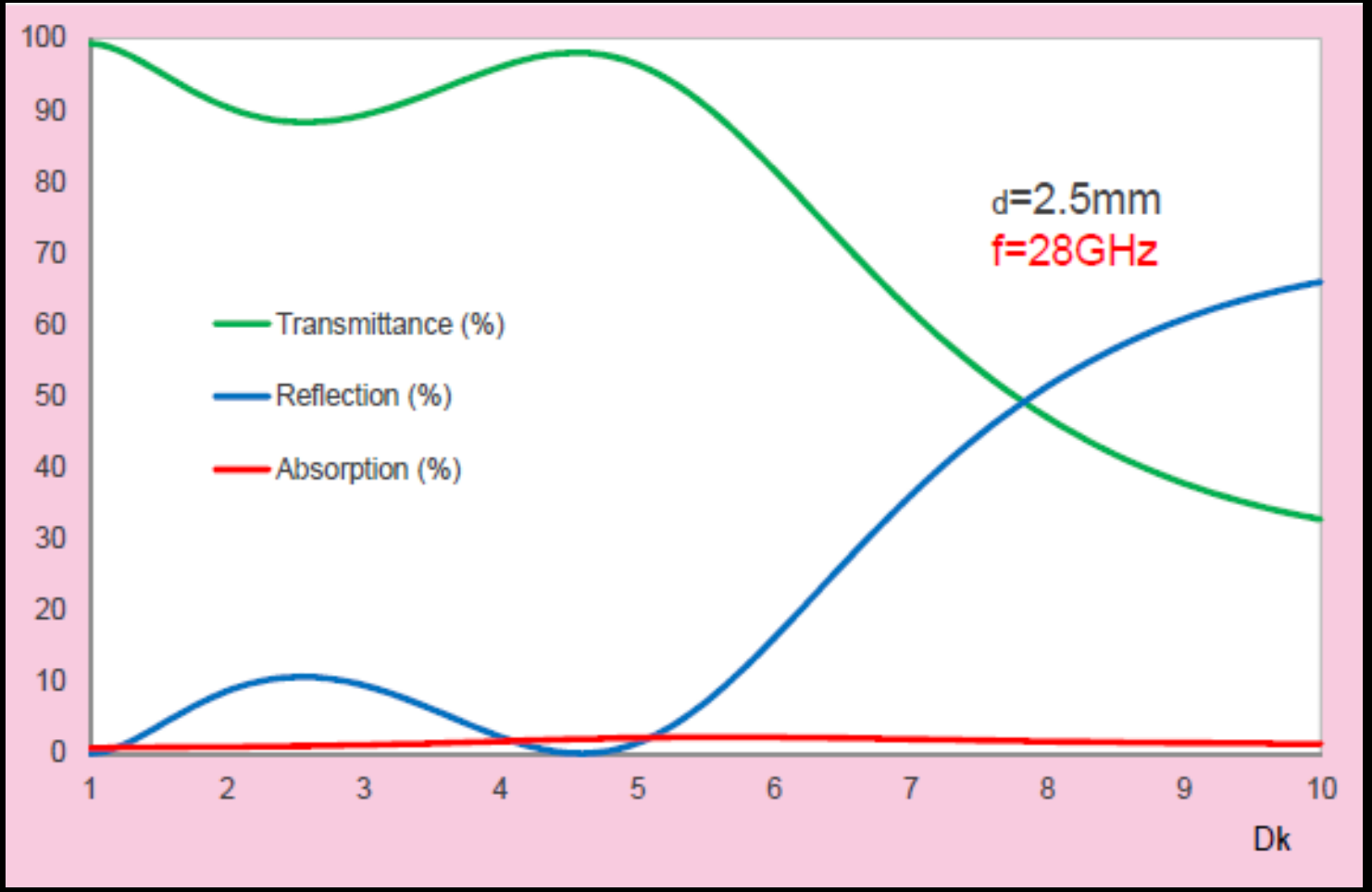
1. **Dielectric constant (Dk)**
2. **Dissipation Factor (Df)**

} Material properties

3. **Part Thickness**
4. **Frequency of Antenna**
5. **Angle of Incidence**
6. **Distance between cover and antenna**

Dielectric Constant (Dk)

Drivers of RF transmission

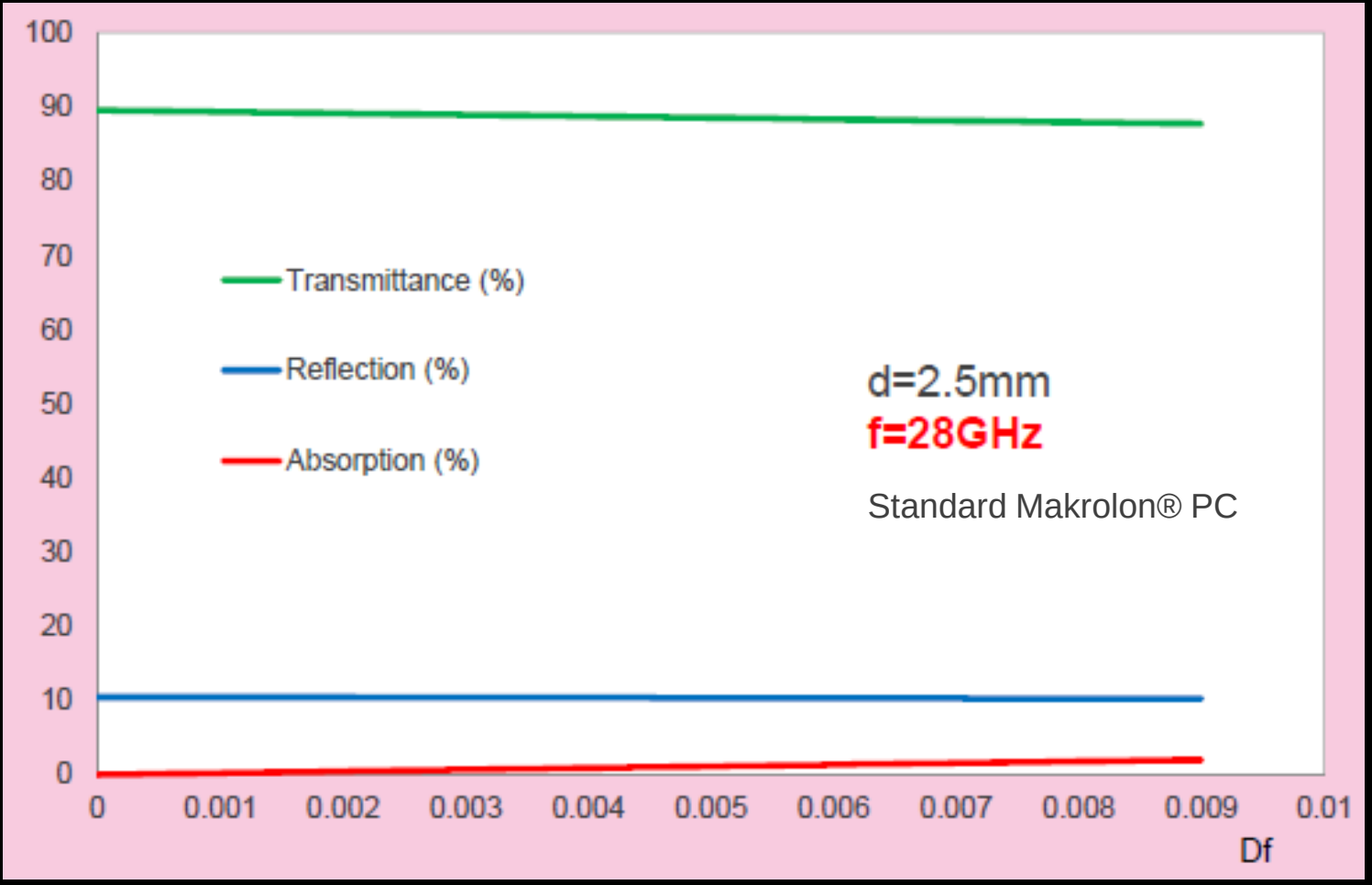


Factors affecting Dk

- PC vs. PC blend
- Material color (~0.05)
- Foaming processes
- Frequency (<6GHz)

Dissipation Factor (Df)

Drivers of RF transmission

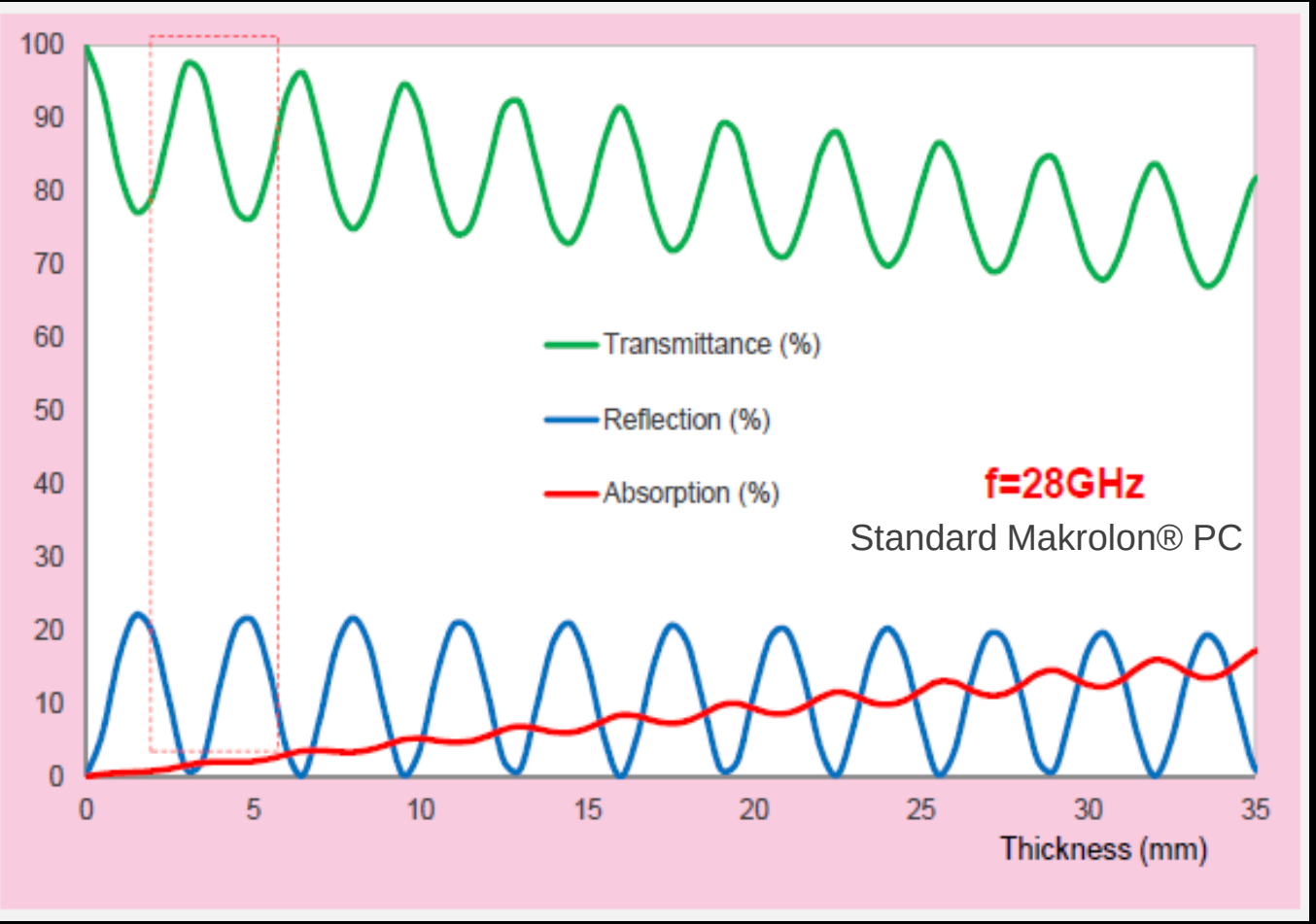


Factors affecting Df

- PC vs. PC blend
- Not as exciting

Part Thickness

Drivers of RF transmission

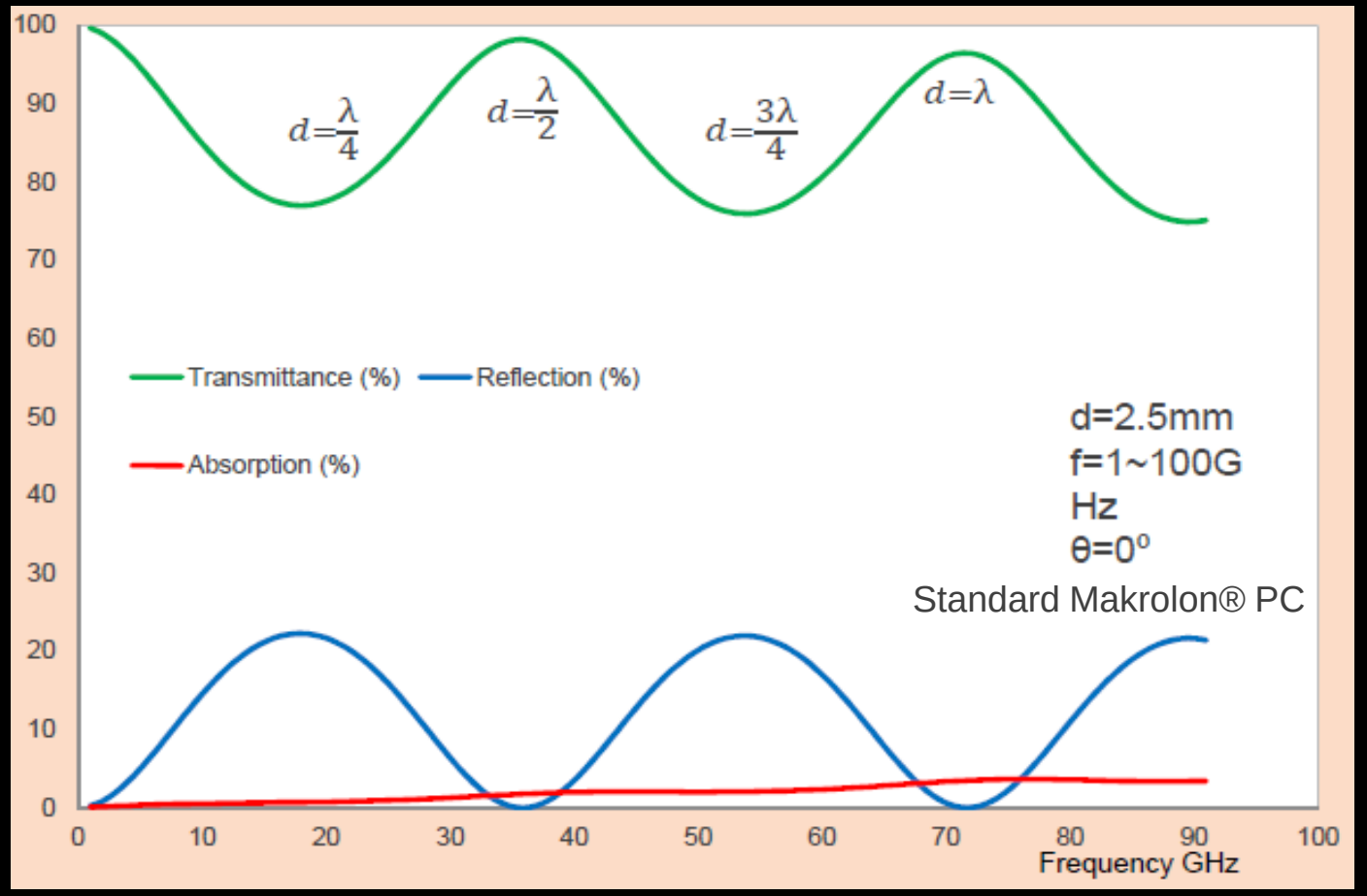


Key Findings

- There is an optimum
- Reflection > Absorption

Frequency

Drivers of RF transmission

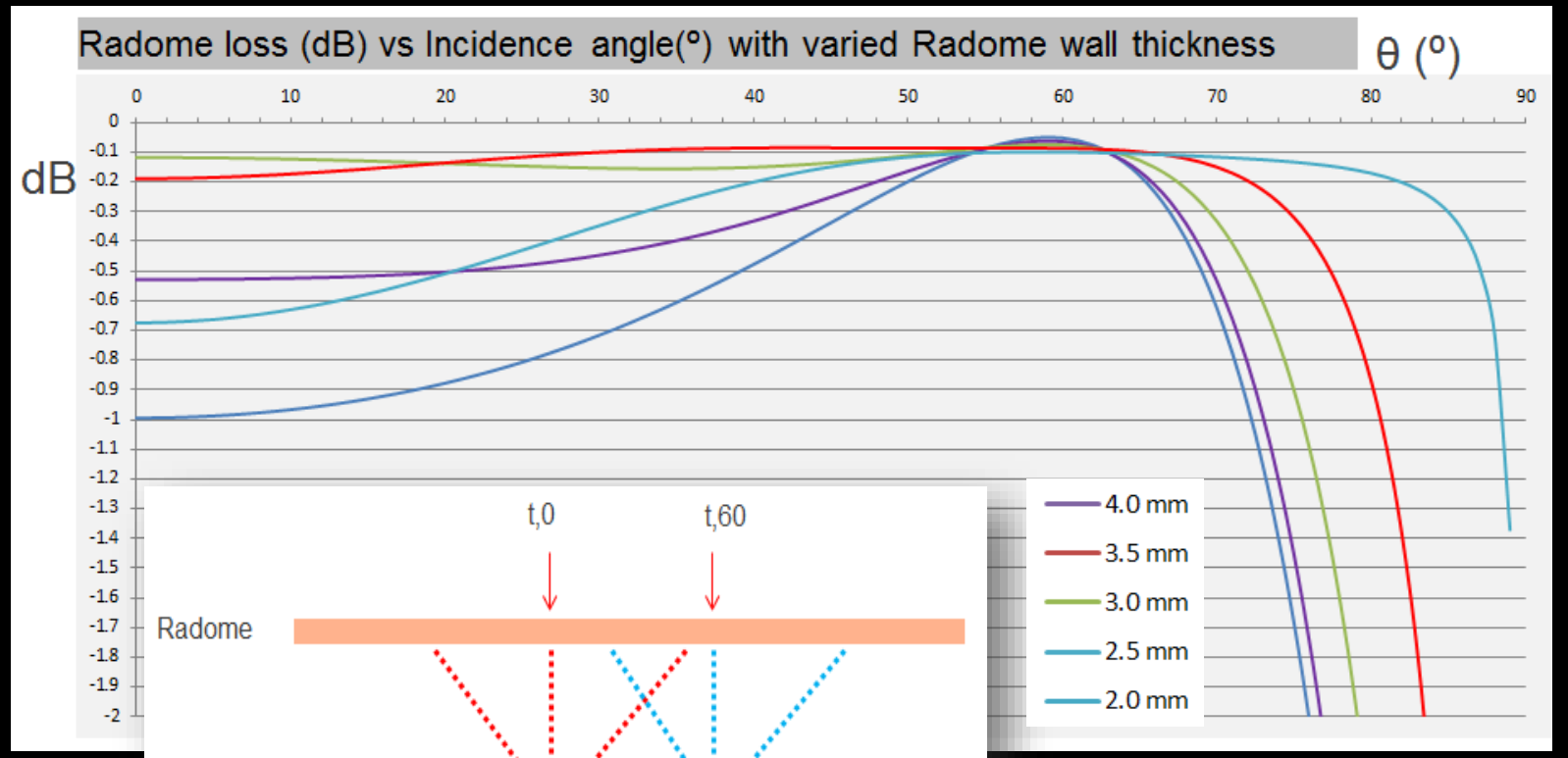


Key Findings

- Design to multiples of wavelength/2!

Angle of Incidence

Drivers of RF transmission

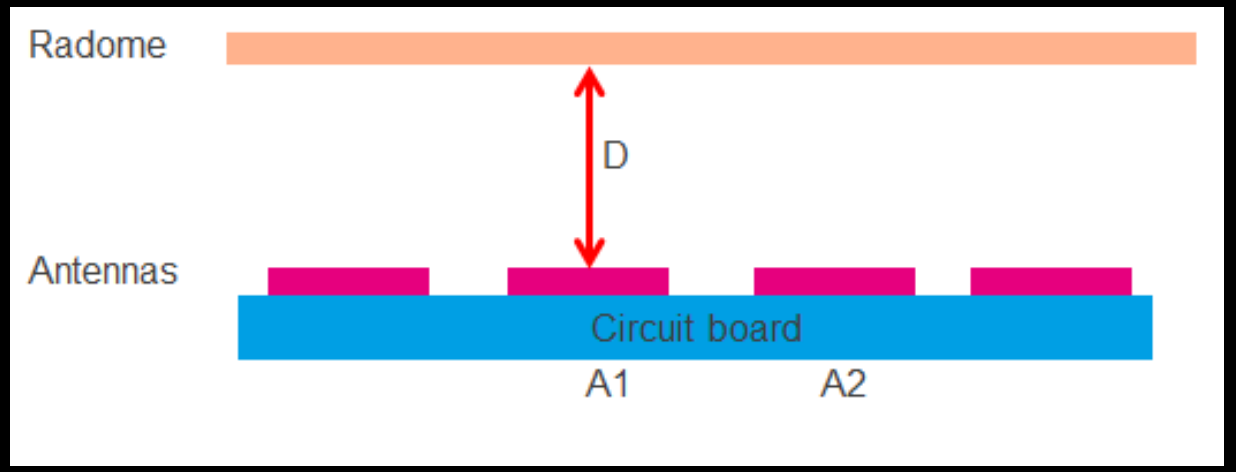


Key Findings

- Transmission typically falls as theta increases
- Covestro can assist in optimizing loss at given angle
- Antennas should be spaced such that there is sufficient “overlap”

Distance Between Cover and Antenna

Drivers of RF transmission

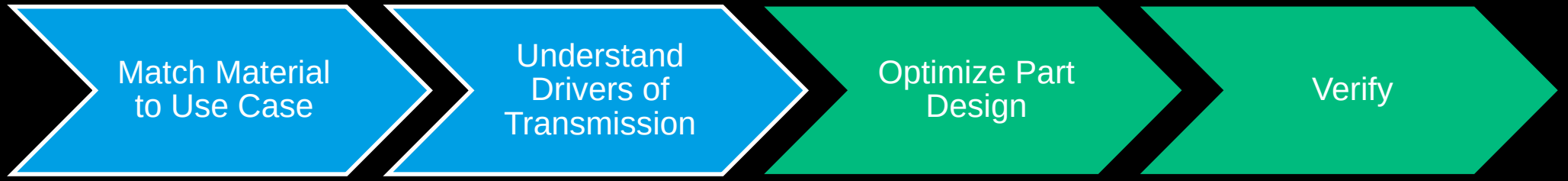


Key Findings

- Distance D = <u>wavelength/2</u>
- Reflections are *in phase* with emitted waves
- No aliasing of signal

Part Design Process

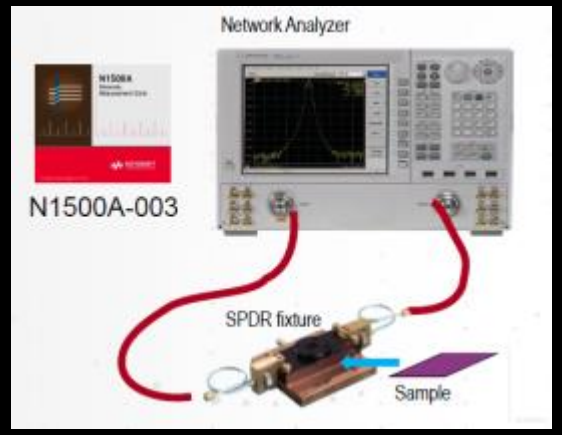
Radome cover

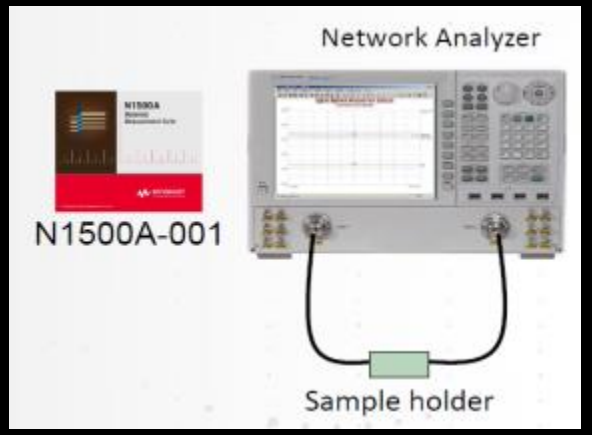


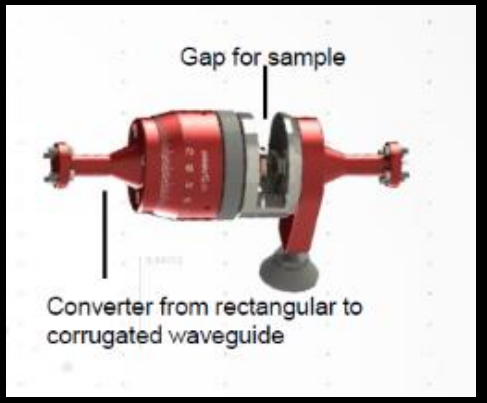
1. **Chosen Material**
2. **Chosen Frequency**
3. **Calculate ideal thickness and distance between radome cover and antenna**
4. **Verify that given thickness is moldable and can meet “non-5G” needs**

Part Design Process

Optimize and Verify signal transmission





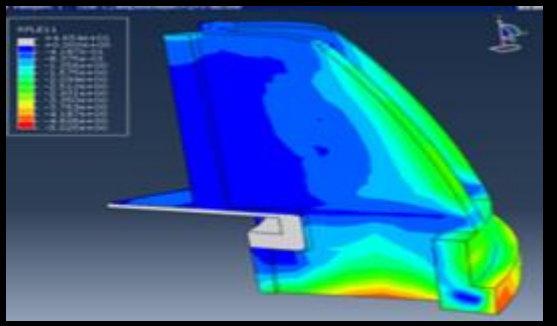


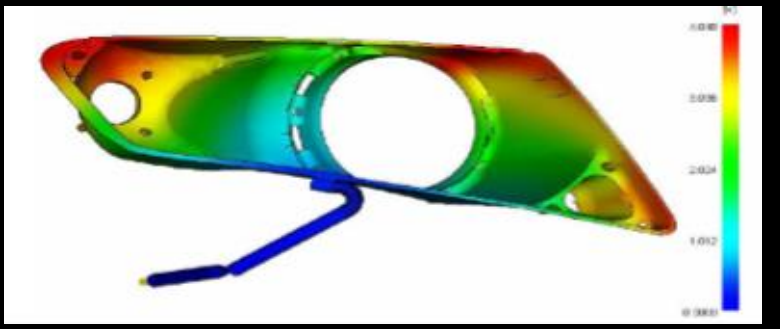
Resonant Cavity							Transmission Line (Waveguide)			Free space	Coaxial
1.1 GHz	2.5 GHz	5.0 GHz	10.0 GHz	15.0 GHz	28.0 GHz	40.0 GHz	18-26.5 GHz	26.5-40 GHz	33-50 GHz	66-110 GHz	30MHz-3.0GHz 1.0GHz-18GHz
Environmental testing : Humidity/Temperature : -40 ℃ ~150 ℃, 25~98 %RH UV aging: 340nm UVA											

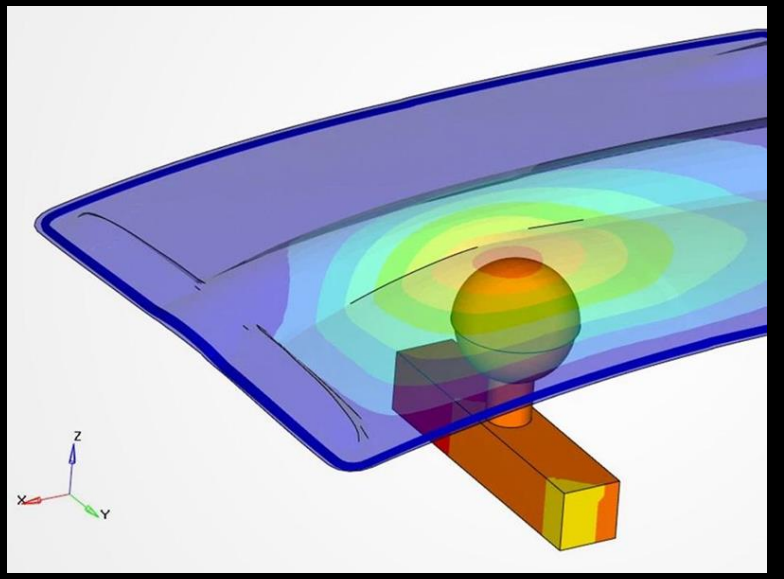
Application Development to Help You Succeed

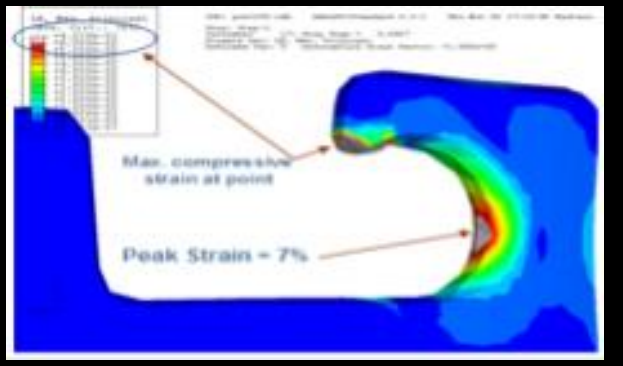
5G housing product design services

- **5G sample testing (resonant cavity, transmission line, free space)**
- **Abaqus CAE for impact, thermal analysis**
- **Moldflow simulations**
- **Chemical resistance testing**
- **Mold design and processing support**
- **Joining trials and knowledge**









Low Temperature Makrolon Flame Retardant Grades

Makrolon® FR60xx

MVR	Low-temperature Ductility		Properties (UL test standards)
	-20°C	**FR6020**	UL746C f1, UL94 V-0@1.5 mm
			Well-balanced outdoor choice
~10	-40°C	**FR6010**	UL746C f1, UL94 V-0@2.0, V-1@1.5
			Low temp impact, V-1 level performance choice
	-40°C	**FR6040**	UL746C f1, UL94 V-0@1.5
			Low temp impact ,V-0 level performance driven choice

MAKROLON® TC

Thermally Conductive Polycarbonate for Heat Management

Thermally Conductive Solutions

Replacing aluminum heat sinks

Example Applications:

- Routers, femtocells (home)
- Picocell / Microcell (hotel, mall)
- Macrocell (neighborhood)
- Base Station (city)

Back cover

Thermally Conductive (TC) polycarbonate

Options:

- Use as the housing itself
- Overmold TC grade on top of flame retardant polycarbonate

Front cover

Flame retardant polycarbonate (Post Consumer Recycle, Low Smoke)

Customized Thermal Conductivity and Electrical Insulation

Comparison of the Makrolon® TC Portfolio

Types of Thermally Conductive Plastics

Electrically conductive
- High to medium thermal conductivity
- Dissipate higher heat loads and hotter point sources – best for aluminum replacement
- Black color appearance

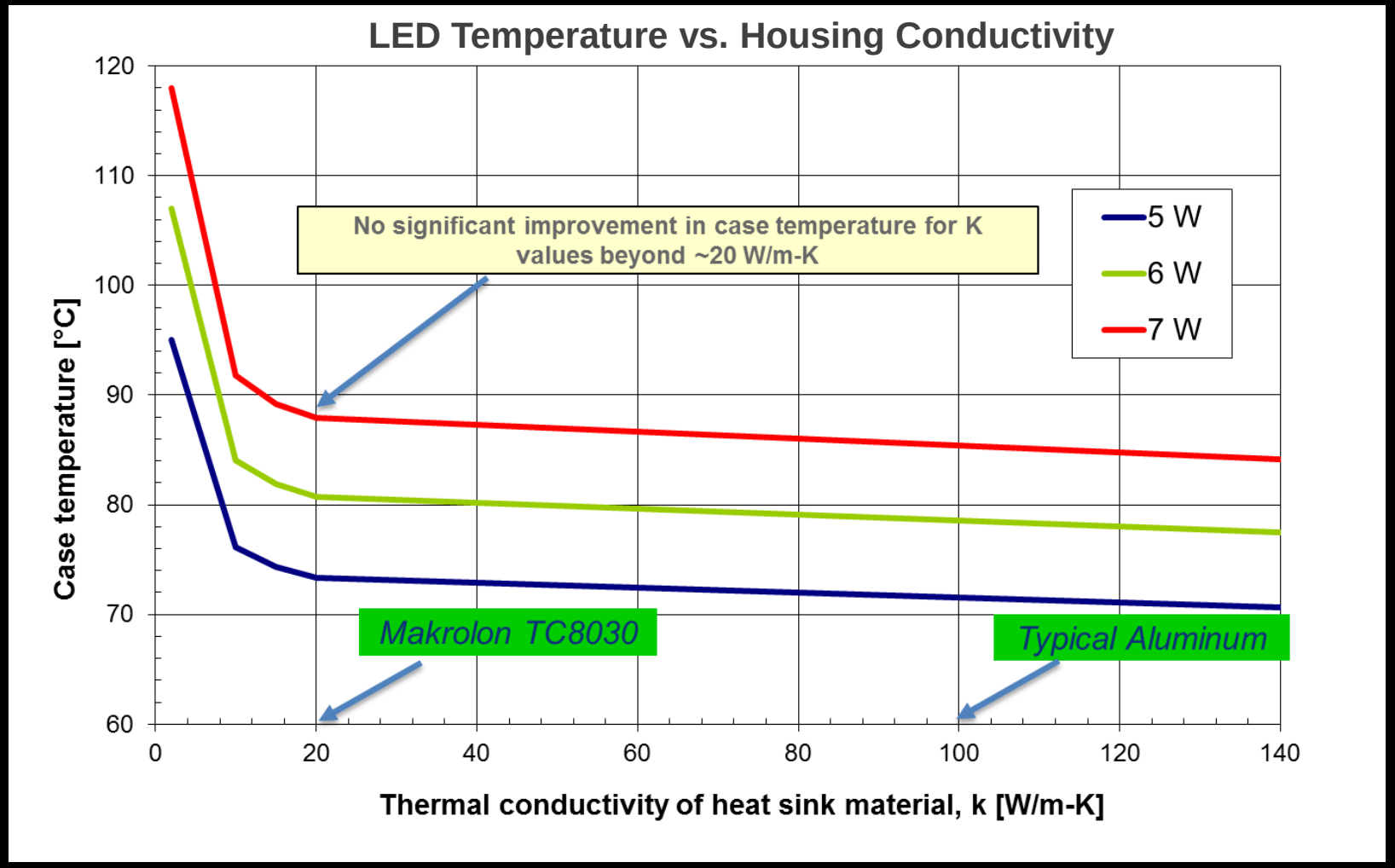
Electrically insulating
- Moderate thermal conductivity
- Dissipate ambient heat
- Electrical Insulation potting may not be necessary
- White color appearance

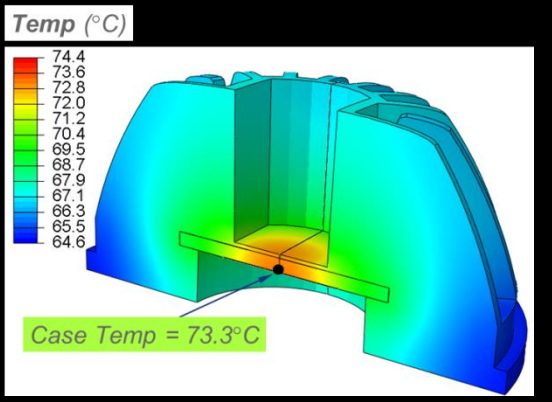
Property	Standard/ Condition/ Unit	TC8030	TC611	TC110	TC110FR
Thermal Conductivity (in-plane)	ASTM E1461 23°C (W/m•K)	14	16	1	1
Density *aluminum is ~ 2.8	g/cc	1.42	1.40	1.45	1.45
Electrical Properties		Conductive	Conductive	Insulating*	Insulating**
UL 94 Flame Class	(mm)	V-0 @ 2.0 f1	V-0 @ 2.0 f1	HB	V-0 @ 1.5 5VA @ 2.0
Spiral flow length	(cm)	16	32	46	46
Process Options		Injection molding	Injection molding	Injection molding / Profile extrusion	Injection molding

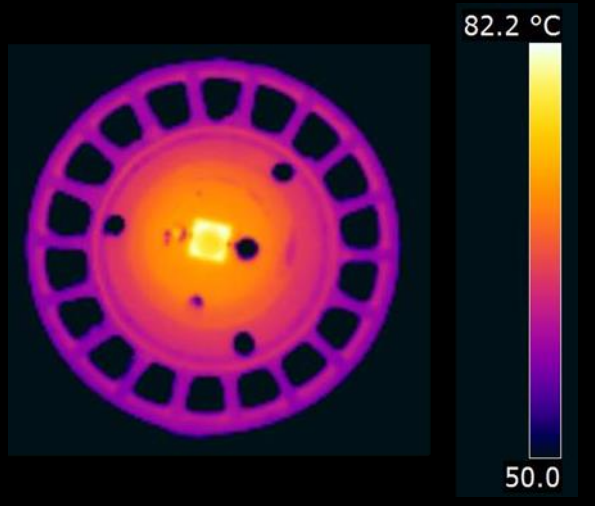
*Volume resistivity >E+15 Ωm, Surface resistivity >E+15 Ω **Volume resistivity >E+16 Ωm, Surface resistivity >E+16 Ω
Volume and surface resistivity based on IEC 60093, 23°C, 50% r. h.

Can Makrolon TC replace Aluminum?

Thermal Conductivity Comparison – Why Makrolon® TC grades works







Low to Higher Powered Applications are Achievable

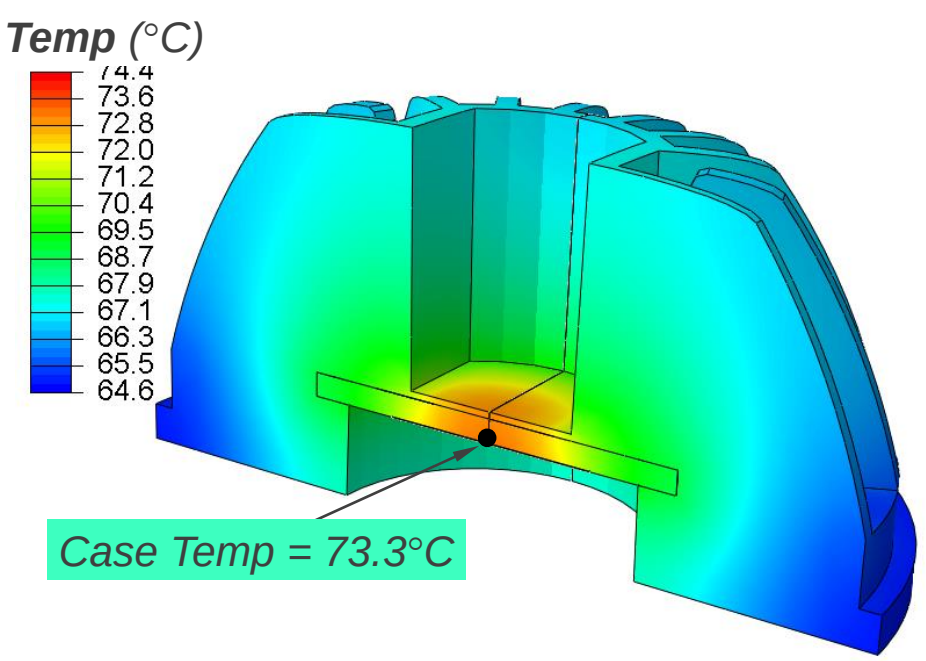
Design Considerations with Makrolon® TC Grades

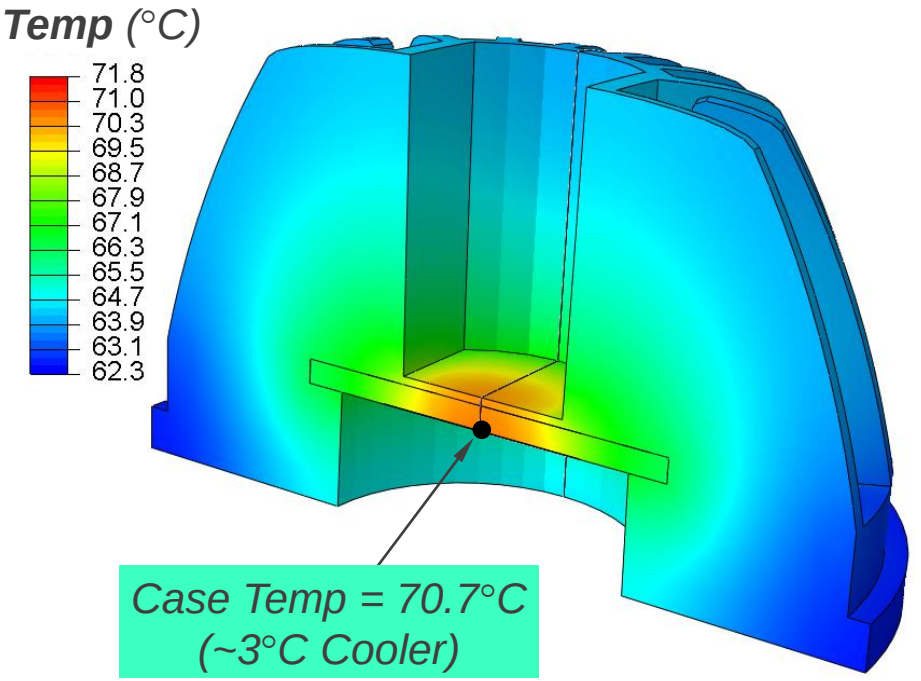
10W LED Lamp

200W LED Array
High Bay Light

Influence of Increased Surface Area on Thermal Performance

Design Considerations with Makrolon® TC Grades



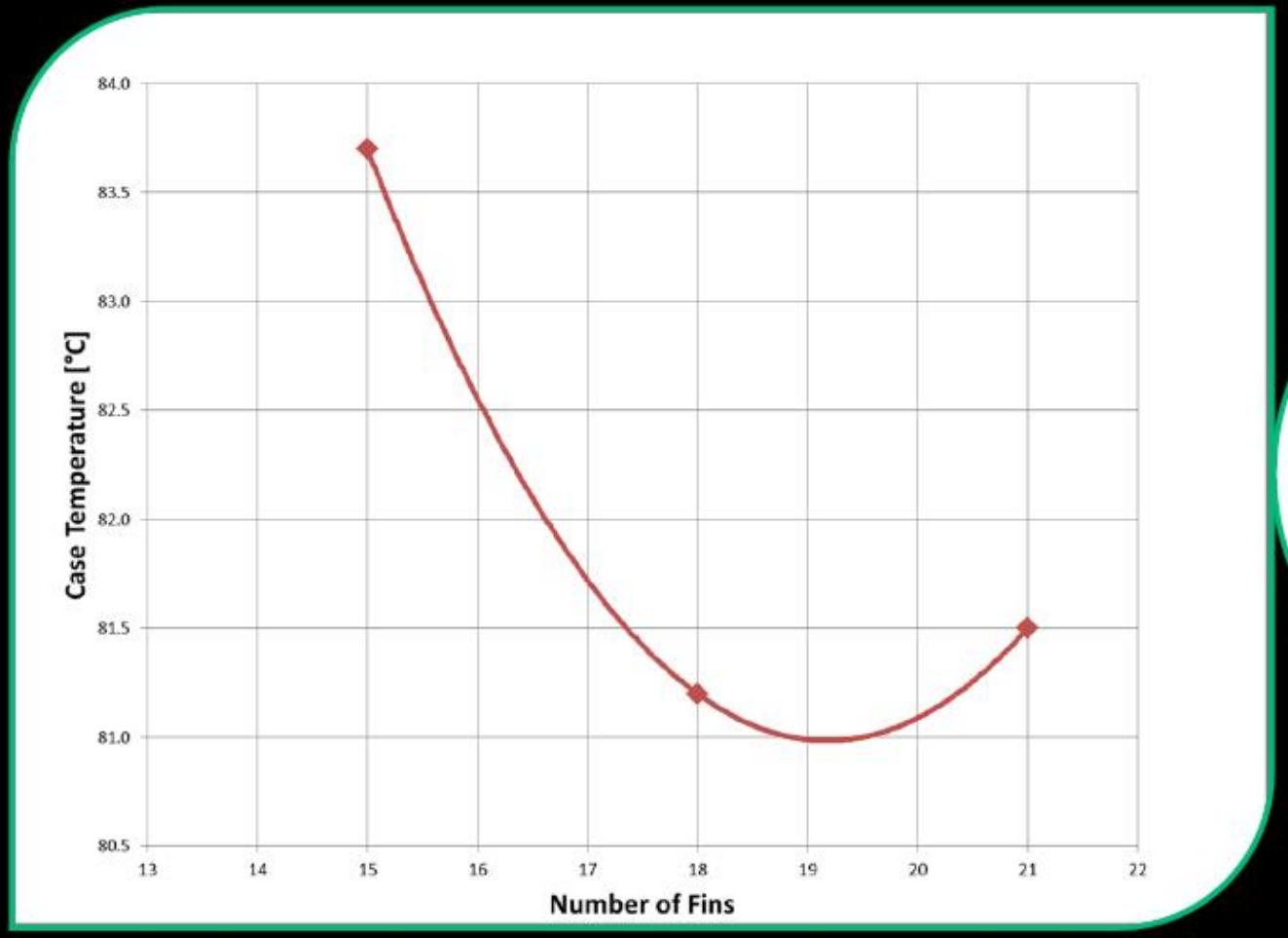


Original Design

20% Taller Design

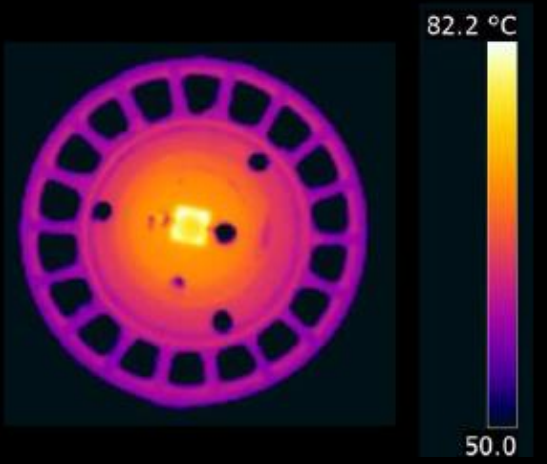
Optimizing thermal convection with cooling fins

Design Considerations with Makrolon® TC Grades



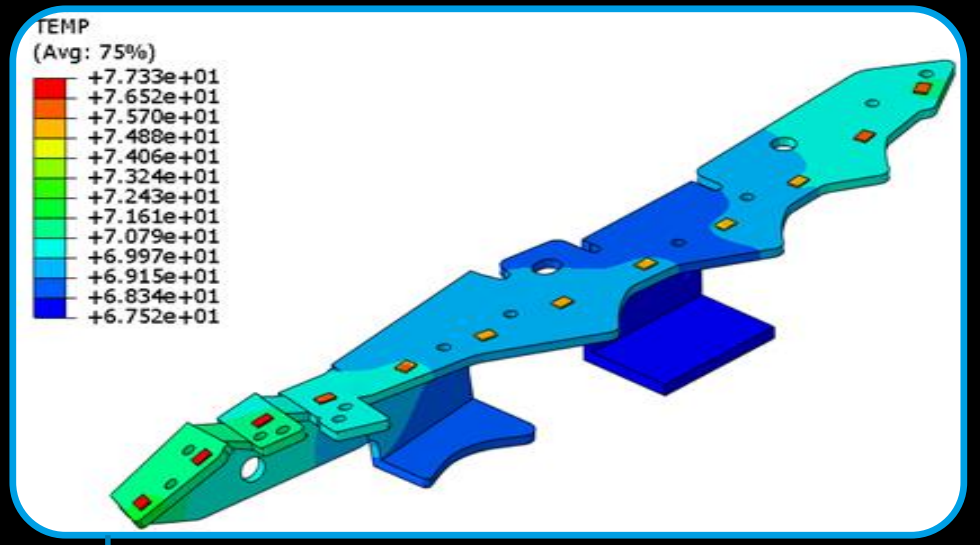
Cooling Fin Optimization

- Added Fins Improve Thermal Performance
- More fins may not always be better



Thermal Performance Improvement *and* Weight Savings

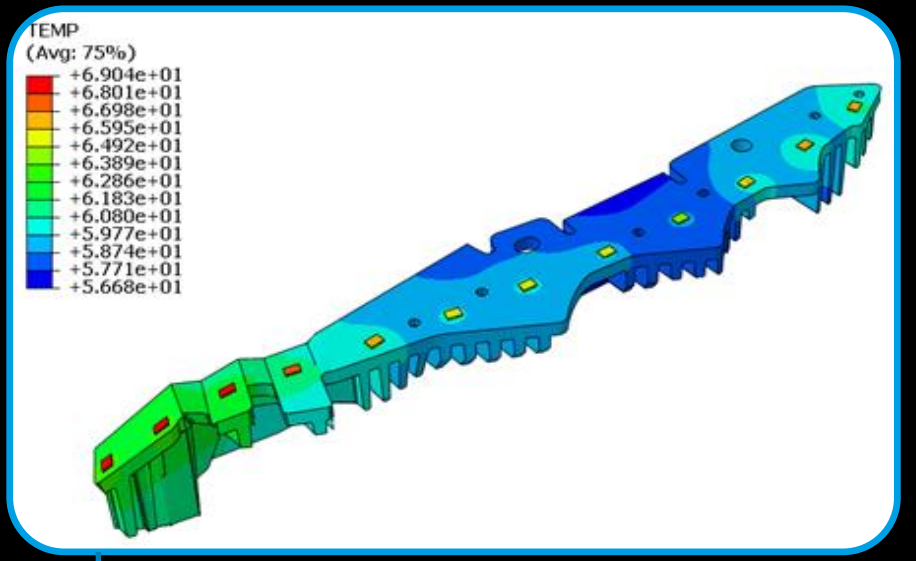
Design Considerations with Makrolon® TC Grades



Stamped Aluminum Heatsink & 0.3W LED

77°C Temp

20g Mass



Optimized ***Makrolon*** Design

69°C Temp

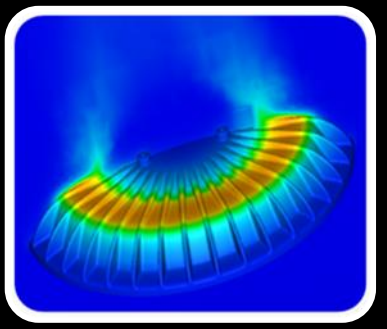
18g Mass

8° to 10°C Cooler

10% Weight Savings

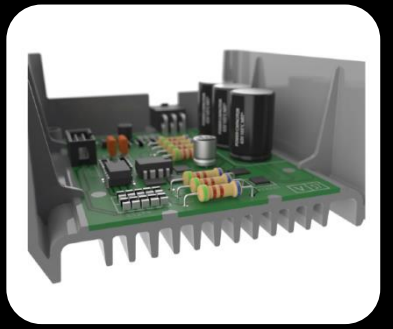
Makrolon Solutions for Heat Management

Commercial Lighting and Electronics



Metal Heat-Sink Replacement

Within 1°C to 3°C of aluminum



Process Step Reductions

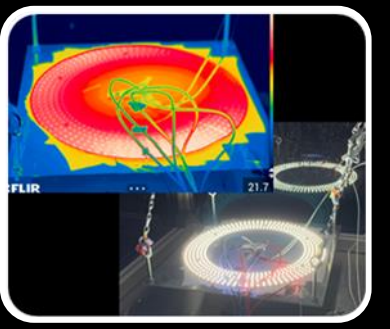
Integrated heatsinks into housings

Consolidation of parts

Paint elimination

Light-Weight Advantage

30% to 45% weight savings over cast aluminum



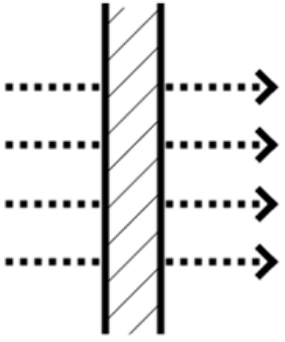
Design Consulting

Solutions up to 300W

Processing / Mold Design

Joining / Bonding

Makrolon® Polycarbonates: Outstanding Property Balance

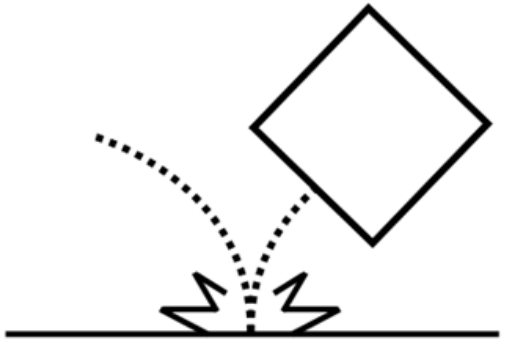


Transparency

Glass-like 88~90%
@ 2.0 mm thickness

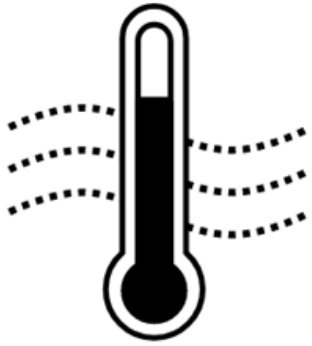
Flame Retardance

UL94 V-0, 5 V



Toughness

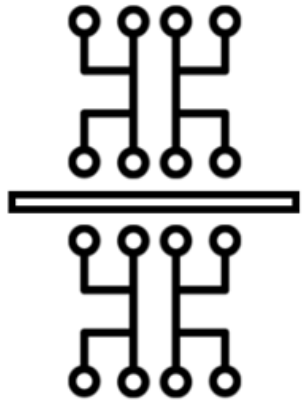
Notched impact resistance:
(IZOD ISO 180A, 23°C, 3.0 mm)
60-90 kJ/m^2



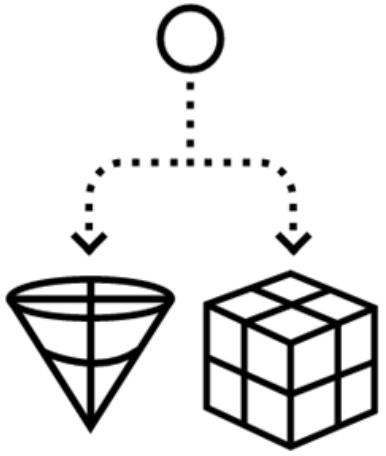
Heat Resistance

Tg ~ 148°C (DSC)
Vicat (ISO 306) ~ 145°C

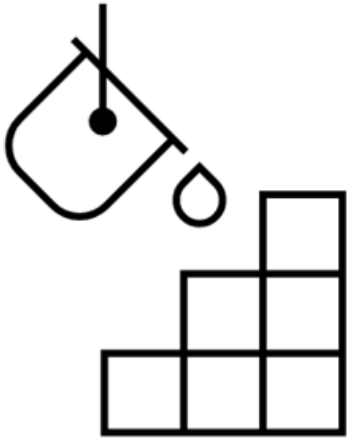
Makrolon® Polycarbonates: Outstanding Property Balance



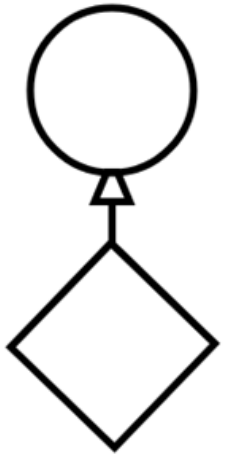
Electrically Insulating
suitable for low and high voltage



Easily Molded
excellent replication of mold surface, reliably consistent

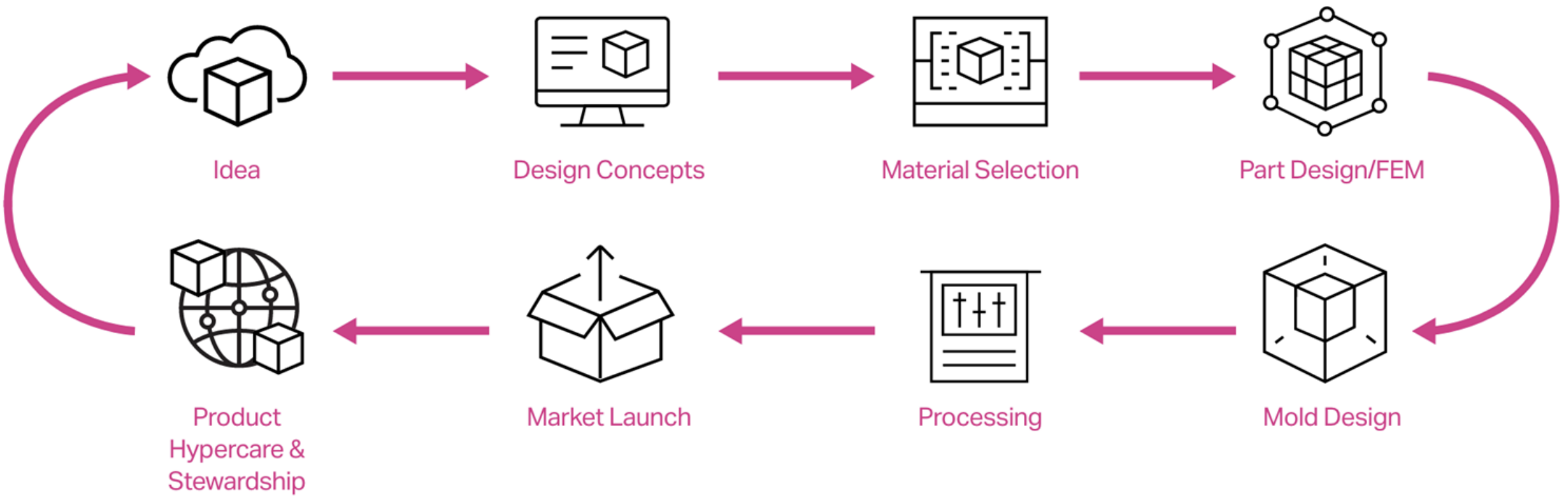


Versatile
flexibility of processing, freedom of design, CMF options



Lightweight
2X lighter than glass
6X lighter than steel
for energy and CO_2 savings

Unleash infinite potential by leveraging Covestro’s development expertise



THANK YOU FOR PARTICIPATING

Q&A