

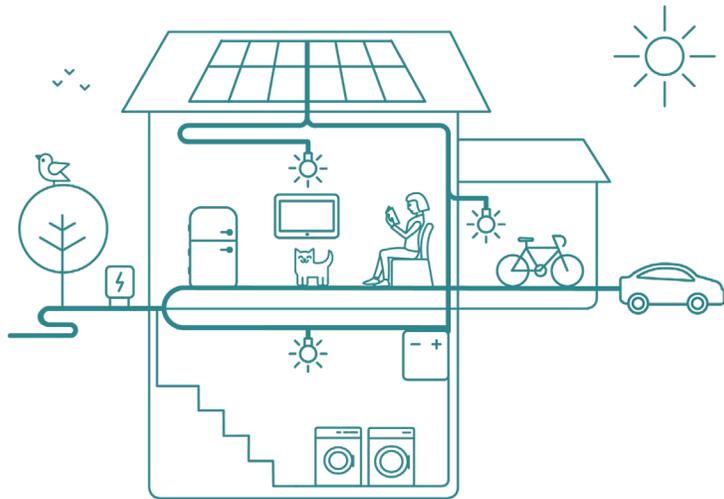
# Are Permanent Magnet Motors the Next “Game-Changer” in Energy Access?

22 April 2021



# Benefits of Efficient, Affordable & High-Quality Appliances

## On Grid



- Save money
- Reduce energy demand
- Mitigate climate change

## Off-Grid



- Reduce energy supply cost
- Increase energy access
- Improve quality of life

# Appliances are Central to Sustainable Development

## High Performing Appliances Help Achieve UN Sustainable Development Goals



# About Efficiency for Access

## Donor Coalition



## Investor Network



## Programme Partners

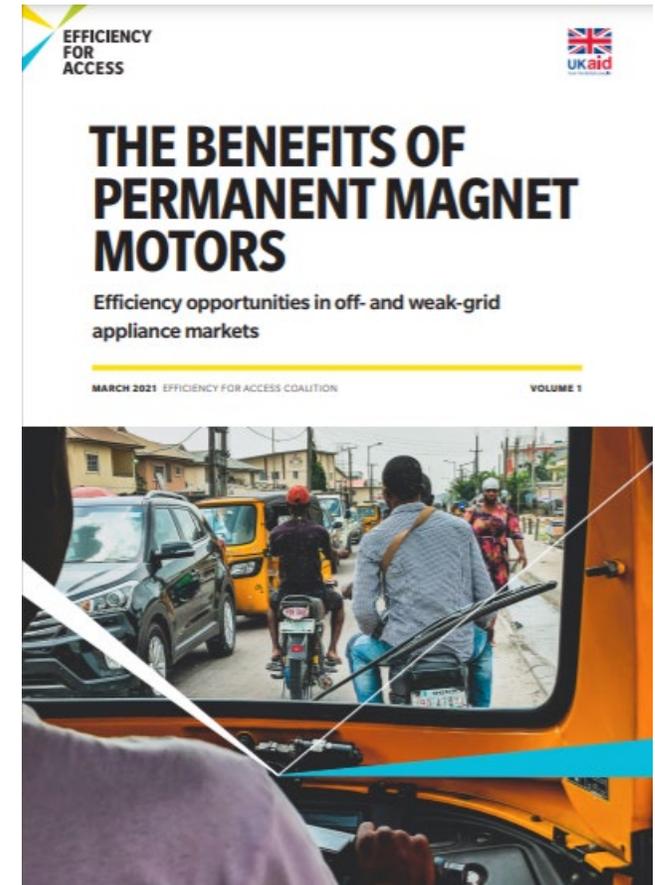


## Secretariat



# Why Motors?

- ▶ As the ‘prime movers’ in many appliances, motors determine the capabilities, power demand, energy consumption and reliability of most off- and weak-grid products.
- ▶ Permanent magnet motors are more efficient than conventional alternating current motors and thus have the potential to deliver significant energy and cost savings to consumers.
- ▶ In 2020, Efficiency for Access partnered with pManifold Business Solutions to conduct the first comprehensive study of permanent magnet motors in off-grid and weak grid markets.



# Agenda

## The Benefits of Permanent Magnet Motors in Off- and Weak Grid Appliance Markets

### Case study: Lessons from the Pakistani fan market

### Moderated discussion and audience Q&A



#### **MODERATOR**

**Stephen Pantano**  
Chief Research Officer  
CLASP



#### **SPEAKER**

**Rahul Bagdia**  
Managing Director  
pManifold Business  
Solutions Pvt. Ltd.



#### **SPEAKER**

**Ankit Agarwal**  
Principle Consultant  
pManifold Business  
Solutions Pvt. Ltd.



#### **SPEAKER**

**Dr. Evan Murimi**  
Jomo Kenyatta  
University of  
Agriculture and  
Technology

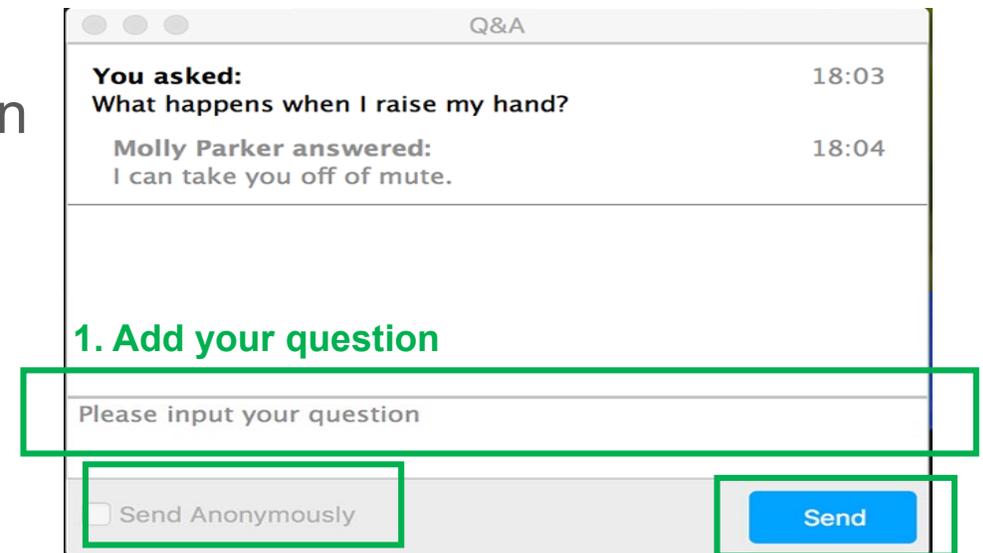


#### **SPEAKER**

**Muhammad Shehryar**  
Founder &  
Managing Director  
Harness Energy

# Asking Questions

- You may submit a question at any point during the webinar using the Q&A feature, rather than the chat feature.
- To submit a question, select the Q&A button located on the task bar.
- You will then be prompted to submit your question publicly or anonymously.
- Attendees may “like” and comment on all questions.



2. Send anonymously or publicly    3. Submit

**EFFICIENCY  
FOR  
ACCESS**



# The Benefits of Permanent Magnet Motors

Efficiency opportunities in off- and weak-grid appliance markets



# Table of Content

---

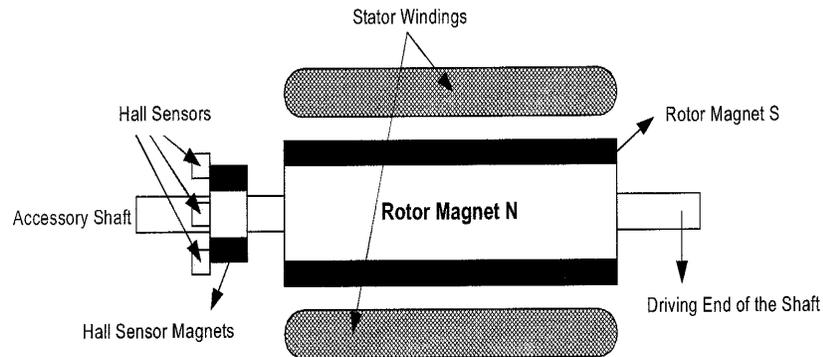
PM Motor – The Superior Technology	10-14
PM Motor Appliance Market Trend and Demand Drivers	15-26
PM Motor's Off- and Weak-grid Potential	27-30
Barriers and Strategies to PM Motor Adoption	31-35

---

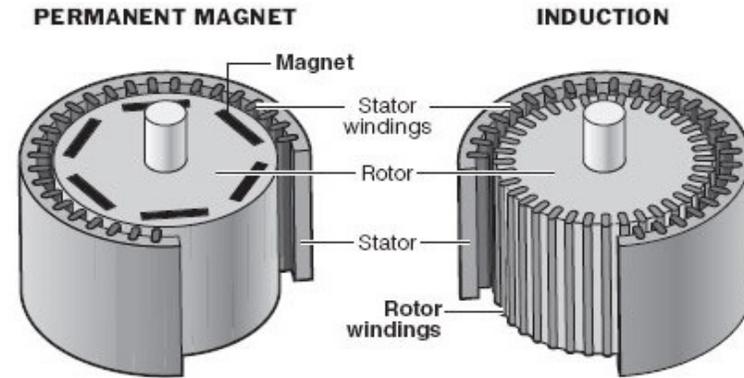
A decorative graphic on a blue background. A yellow triangle points to the right, with its vertex at the right edge of the frame. A white line also points to the right, with its vertex at the right edge of the frame, positioned below the yellow triangle. The text 'PM Motor – The Superior Technology' is centered horizontally and positioned between the two lines.

# PM Motor – The Superior Technology

# Architecture of a PM Motor



**Anatomy of a PM Motor**



**PM Motor vs Induction Motor**

Electronic switching commutators eliminate commutation friction making PM motors more efficient compared to the AC induction or universal motors.

## Future Technology Trends for PM Motor

- ✓ Axial Flux Design
- ✓ Field Oriented Control
- ✓ Soft Magnetic Composites
- ✓ Advanced Remote Monitoring
- ✓ Ferrite Magnet
- ✓ Single inverter for motors
- ✓ Integrated circuit based controllers
- ✓ Sensor-less control techniques

# PM Motor advantages over other motor types makes it more suitable for off- and weak-grid applications

Attribute	AC INDUCTION MOTOR		UNIVERSAL MOTOR		PM MOTOR	
	Motor	Controller	Motor	Controller	Motor	Controller
Construction	Simple	Simple	Medium	Simple	Simple	Complex
Cost	Low	Low	Medium	Low	Medium	High
Efficiency	Low		Medium		High	
Smart features	Low	Low	Medium	Low	Many	Many
Versatility	Low	Low	Medium	Low	High	High
Noise levels	Medium		High		Low	

Translating to better suitability for off- and weak- grid applications



# Energy savings combats price premium of PM motors resulting in lower life cycle cost of appliances (1/2)

CATEGORY	ATTRIBUTES	 CEILING FAN (1.2 M)	 DIRECT COOL REFRIGERATOR (200 L)	 WASHING MACHINE (7.5 KG)
Price	Price premium for PM motor appliance (%)	<b>63%</b>	<b>9%</b>	<b>12%</b>
	Price of PM motor and controller in appliance price (%)	<b>35% to 45%</b>	<b>~3%</b>	<b>~8%</b>
Performance	Energy efficiency savings by PM motor (%)	<b>~38%</b>	<b>~22%</b>	<b>~28%</b>
	Key Benefit from PM motor	Low voltage operability	Variable speed control	Belt Drive Elimination
	Other functional advantage from PM motor	<b>38%</b> reduction in input power [W]	<b>27%</b> reduction in minimum operating voltage [V]	<b>28%</b> reduction in water utilisation
Returns	PM motor appliance Payback	<b>3.5 years</b>	<b>6.2 years</b>	<b>26.2 years</b>
	Total LCC of PM motor appliance against conventional motor appliance (%)	<b>17%</b> lower	<b>3%</b> lower	<b>4%</b> higher

# Energy savings combats price premium of PM motors resulting in lower life cycle cost of appliances (2/2)

CATEGORY	ATTRIBUTES	 SOLAR WATER PUMP (3 HP)	 DEEP FREEZER (100 L)	 ELECTRIC 2-WHEELER (100 KG)
Price	Price premium for PM motor appliance (%)	~106%	3%	67%
	Price of PM motor and controller in appliance price (%)	15% to 20%	4%	6%
Performance	Energy efficiency savings by PM motor (%)	Not Relevant	42%	82%
	Key Benefit from PM motor	Low voltage operability and early start-ability	Variable speed control	Accurate Torque Response
	Other functional advantage from PM motor	9% greater water output [litres per day]	34% reduction in minimum operating voltage [V]	84% reduction in cost per km
Returns	PM motor appliance Payback	11 months	4 months	3.5 years
	Total LCC of PM motor appliance against conventional motor appliance (%)	~89% lower	25% lower	6% lower

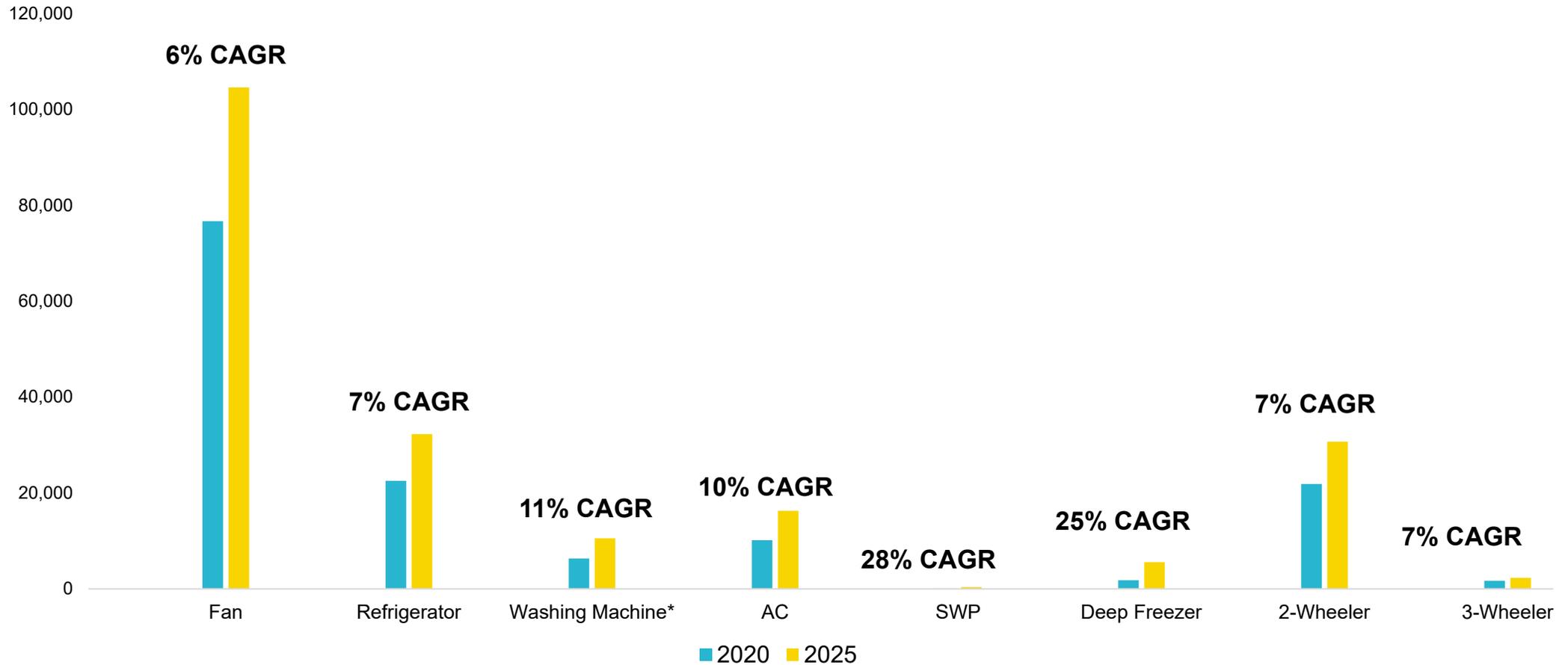
Please note: Comparison of 1) PM Motor SWP is with Diesel operated AC Induction motor pump (except for water output) and 2) e-2W is with ICE 2W



# PM Motor Appliance Market Trend and Demand Drivers

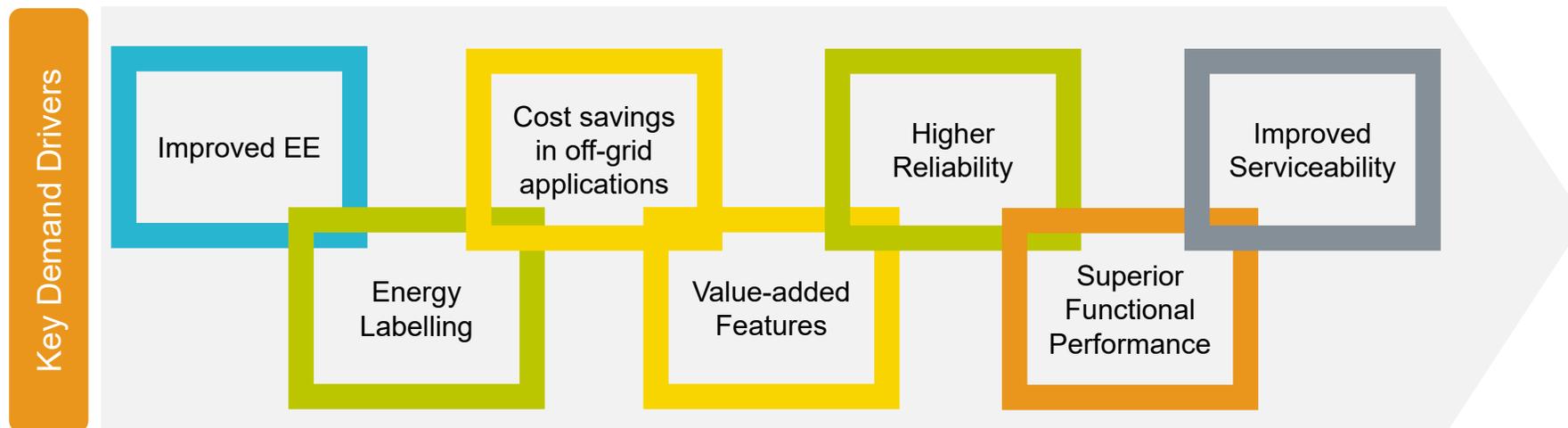
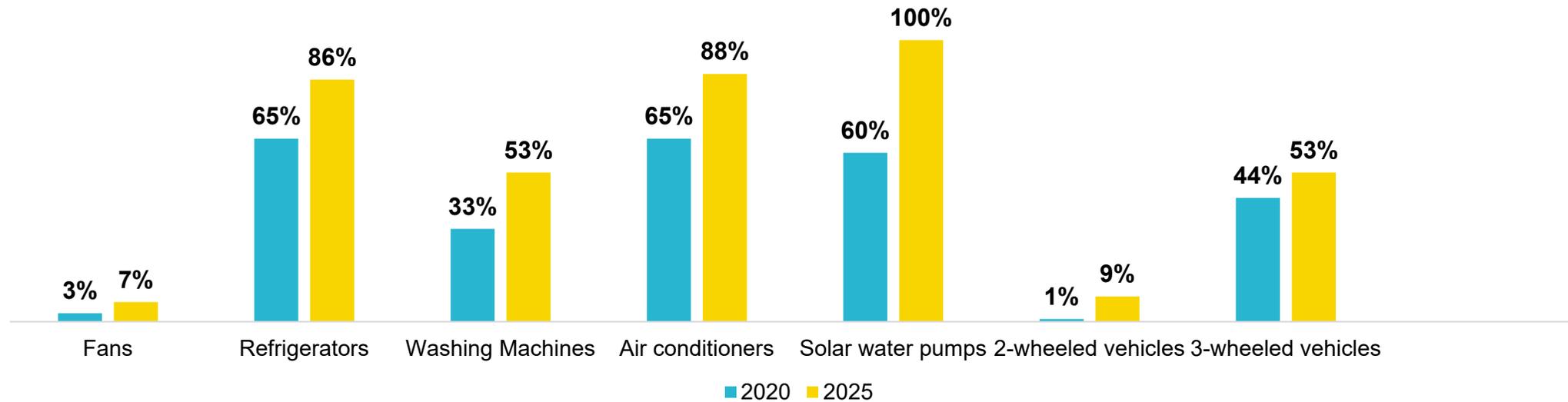
# Market Trend of overall Appliances (2020-2025) | South Asia

Estimated Annual Appliance Sales ('000 units)

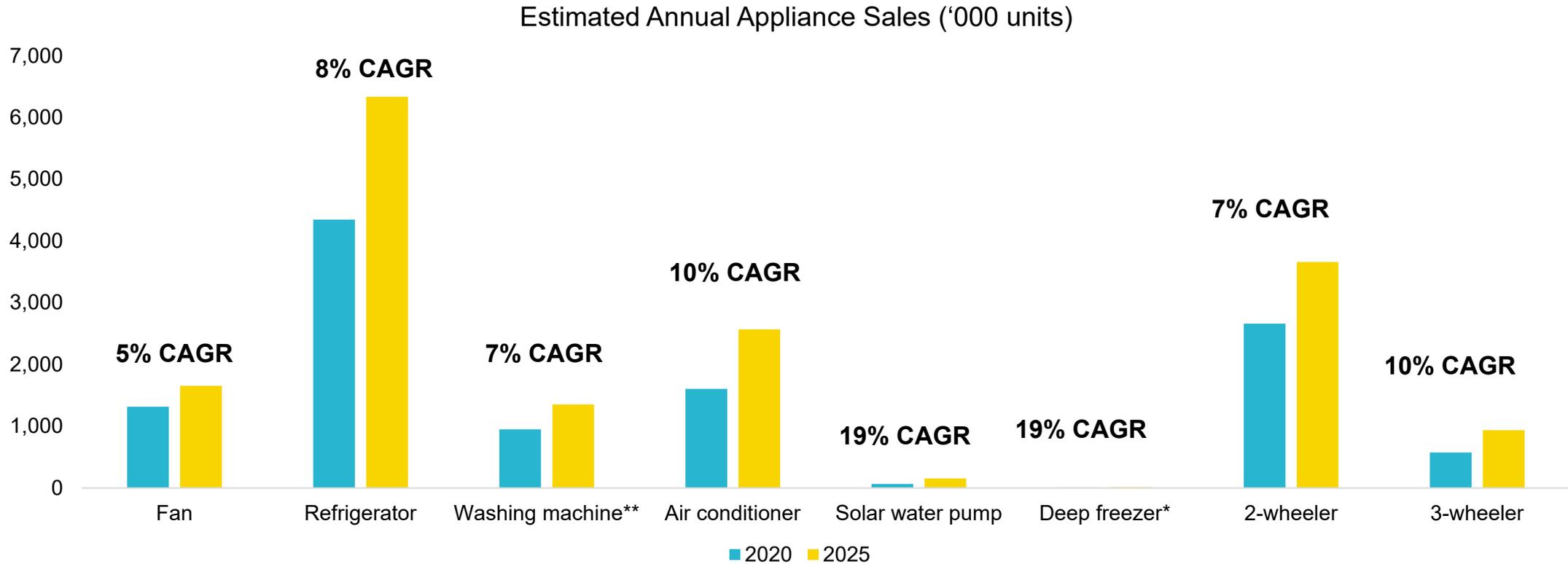


\*Only fully-automatic washing machines are considered

# PM Motor penetration rate in Appliances | South Asia



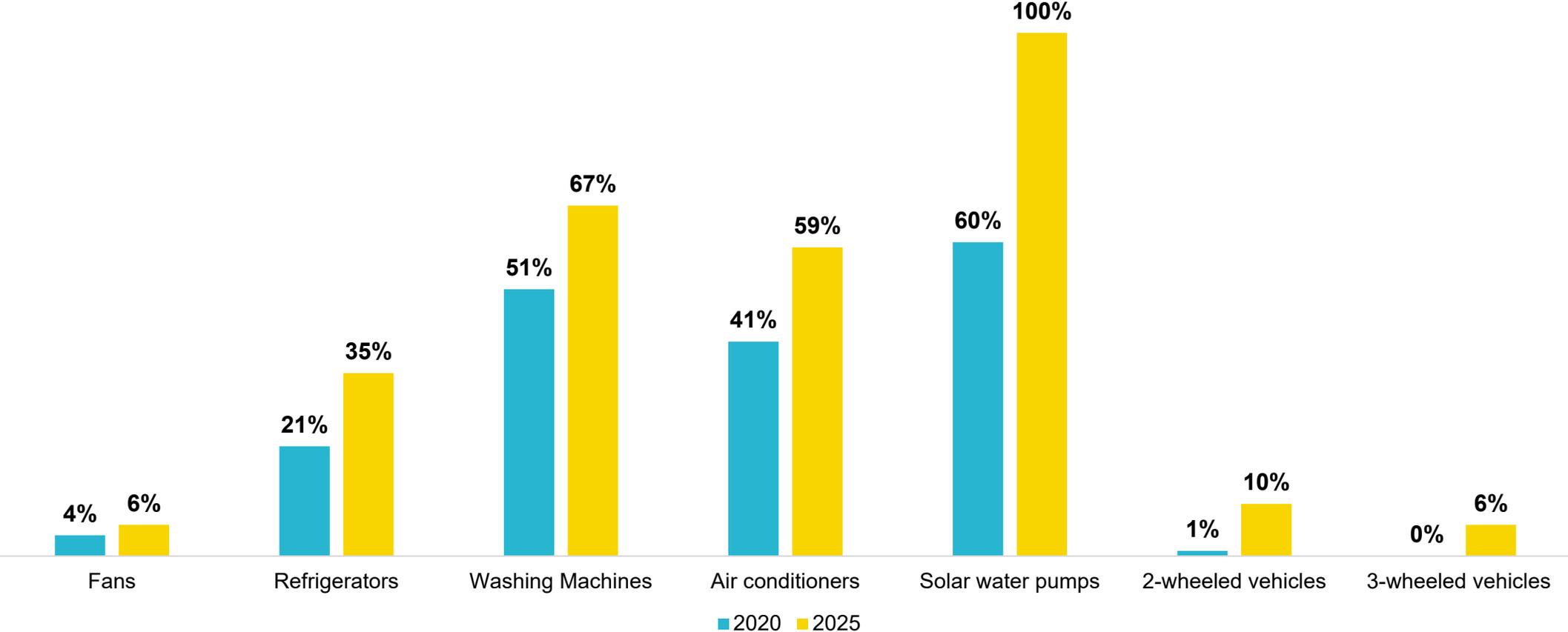
# Market Trend of overall Appliances (2020-2025) | SSA



\*The represented figures for Deep Freezers are PM motor appliance sales and not overall appliance sales

\*\*Only fully-automatic washing machines are considered

# PM Motor penetration rate in Appliances | SSA



# Household Appliances in SSA (1/4)

## Fans

- Have the largest total market among the household appliances considered in this study
- Have the lowest PM motor penetration rate (4%)
- PM motor accounts for ~40% of a fan's total price
- PM motor fans are sold at a premium price, thus do not cater to mass market
- PM motor adoption will be driven by,
  - Growth in solar off-grid market,
  - Government standards &
  - Incentives pushing for EE Appliances



# Household Appliances in SSA (2/4)

## Refrigerators

- Expected to grow by CAGR ~8% till 2025
- PM motors refrigerators are commonly referred to as inverter refrigerators
- Inverter refrigerators account for about 21% market share in 2020 which will increase to 35% by 2025
- High PM motor penetration rate due to PM motor's ability to provide value added features such as Quieter operation, Consumer value, and higher EE



# Household Appliances in SSA (3/4)

## Washing machines

- ▶ Limited adoption of PM motors in semi-automatic washing machines- focus on fully automatic
- ▶ Fully automatic accounts for ~46% sales; expected to grow at CAGR of 7%; to reach 1.4 million units of annual sales by 2025
- ▶ PM motor penetration rate at 51% in 2020; expected to reach 67% by 2025
- ▶ Increased adoption of PM motors will be due to,
  - increasing disposable income
  - increase in working population



# Household Appliances in SSA (4/4)

## Air conditioners

- Annual sales of 2.6 million units expected by 2025 growing at a CAGR of 10% from 2020
- Split ACs are more popular than window ACs
- Increased adoption of ACs due to
  - Increased income
  - Rising temperature & humidity
- PM motors penetration rate in ACs is expected to grow from 41% in 2020 to 59% in 2025
- Adoption of Inverter ACs will be due to PM motor's ability to enable value-added features



# Productive Use Appliances in SSA (1/2)

## Solar water pumps

- Higher efficiency & PM motor's compatibility with SWPs has enabled high penetration
- PM motor penetration rate estimated at 60% in 2020; expected to reach 100% by 2025



# Productive Use Appliances in SSA (2/2)

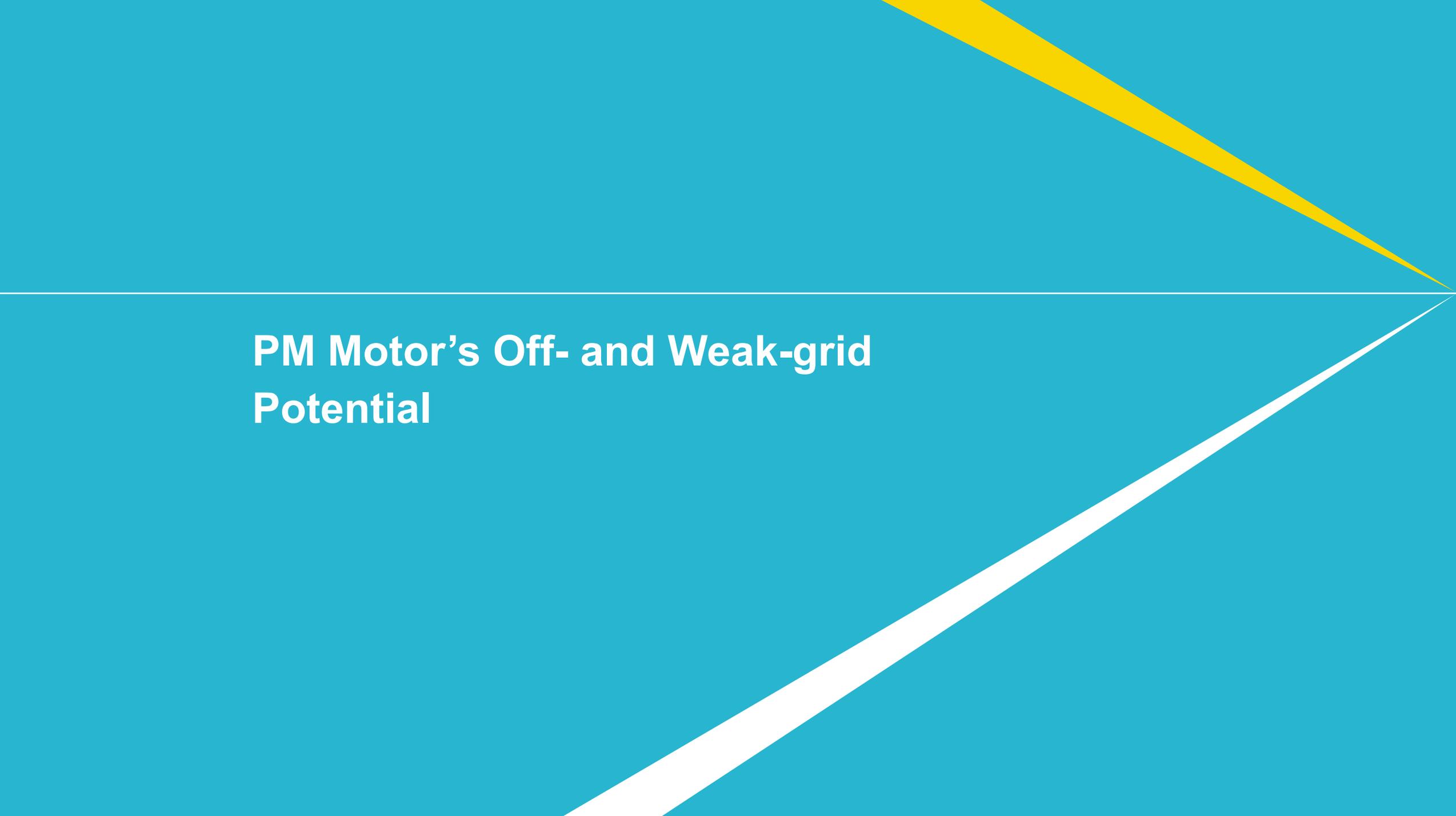
## Deep freezer

- ▶ Limited baseline data available for deep freezers with conventional motors
- ▶ PM motor appliance annual sales estimated to reach ~12,000 units by 2025, growing at 19% CAGR
- ▶ Demand drivers for PM motor adoption in deep freezers are,
  - Energy labelling programmes
  - Supportive governmental policies



## Electric 2 and 3 wheelers

- 2W and 3W vehicle segments have seen phenomenal growth over the last decade
  - Growth due to increasing population, growing income, increasing urbanisation, and poor public transport networks
- By 2025, 3.6 million 2Ws will be sold in SSA
- 2W mainly operates as commercial taxi
- 3W market expected to be relatively low
- e-2W expected to be the next big market for PM motors
- Key drivers for e-2W and e-3W are,
  - Climate change awareness
  - Low operating cost
  - Favourable government policy and incentives
  - Improved customer awareness
  - Facilitation of financing



# PM Motor's Off- and Weak-grid Potential

# Characterisation of Off- and Weak-grid Markets | SSA (1/2)

Appliance	Current adoption trend	Current affordability	Priority of the appliance	Supply chain	Market potential of PM appliance
<b>Household Appliance</b>					
Fans	High	High (price sensitive market and quality can be compromised)	High	Low	High (low HH electrification rate)
Air conditioners	Negligible	Low	Low	Negligible	Negligible
Washing machines	Negligible	Medium	Low (other appliances are top priority)	Negligible	Negligible
Refrigerators	Low	Medium	Medium	Low	High (use in food and vaccine storage)

# Characterisation of Off- and Weak-grid Markets | SSA (2/2)

Appliance	Current adoption trend	Current affordability	Priority	Supply chain	Market potential of PM Appliance
<b>Productive Use Appliances</b>					
Solar water pumps	Low	Low (lack of subsidies)	High	Medium	High (huge unirrigated land)
Deep freezers	Low	Medium (provided access to finance is available)	High	Low	High (use in food and vaccine storage)
<b>Transportation</b>					
E-2W	Low	Low (reliant on suitability as taxis)	High	Low	Medium (volumes are small at a country level)
E-3W	Negligible	Low (limited market need)	Low (as 2W are used as taxis)	Negligible	Low

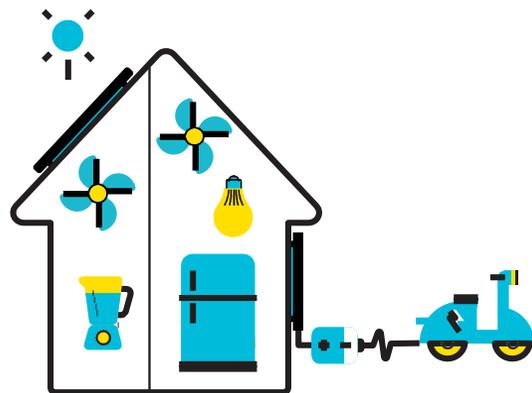
# Case Study | Off-grid household using Energy Efficient Appliances

## Appliances

Appliance	Conventional (W)	EE (W)	Savings
Light	80	10	87% ↓
Mixer	510	340	33% ↓
Fan	104	64	38% ↓
Refrigerator	100	78	22% ↓
Mobile charger	20	20	-
Battery charger	395	193	51% ↓

## PV Solar + Battery Power Supply

Parameter	Conventional Appliance	EE Appliance	Savings
PV Panel Peak Wattage	1,814 W	1,057 W	42% ↓
Cost of PV Panel	\$856	\$ 535	37% ↓
Recommended Battery	2.5 kWh/ 220 A-hr	1.5 kWh/ 150 A-hr	40% ↓
Cost of Battery	\$276	\$147	47% ↓
Total cost	\$1131	\$682	40% ↓
Additional cost of EE Appliance	-	\$77.5	20% ↑
<b>Net Savings</b>	<b>20% net savings</b> on cost for EE Appliances		



If higher capacity PV panels for conventional appliances are already installed, spare capacity freed up by EE appliances can be used to charge e-2W/ e-3W

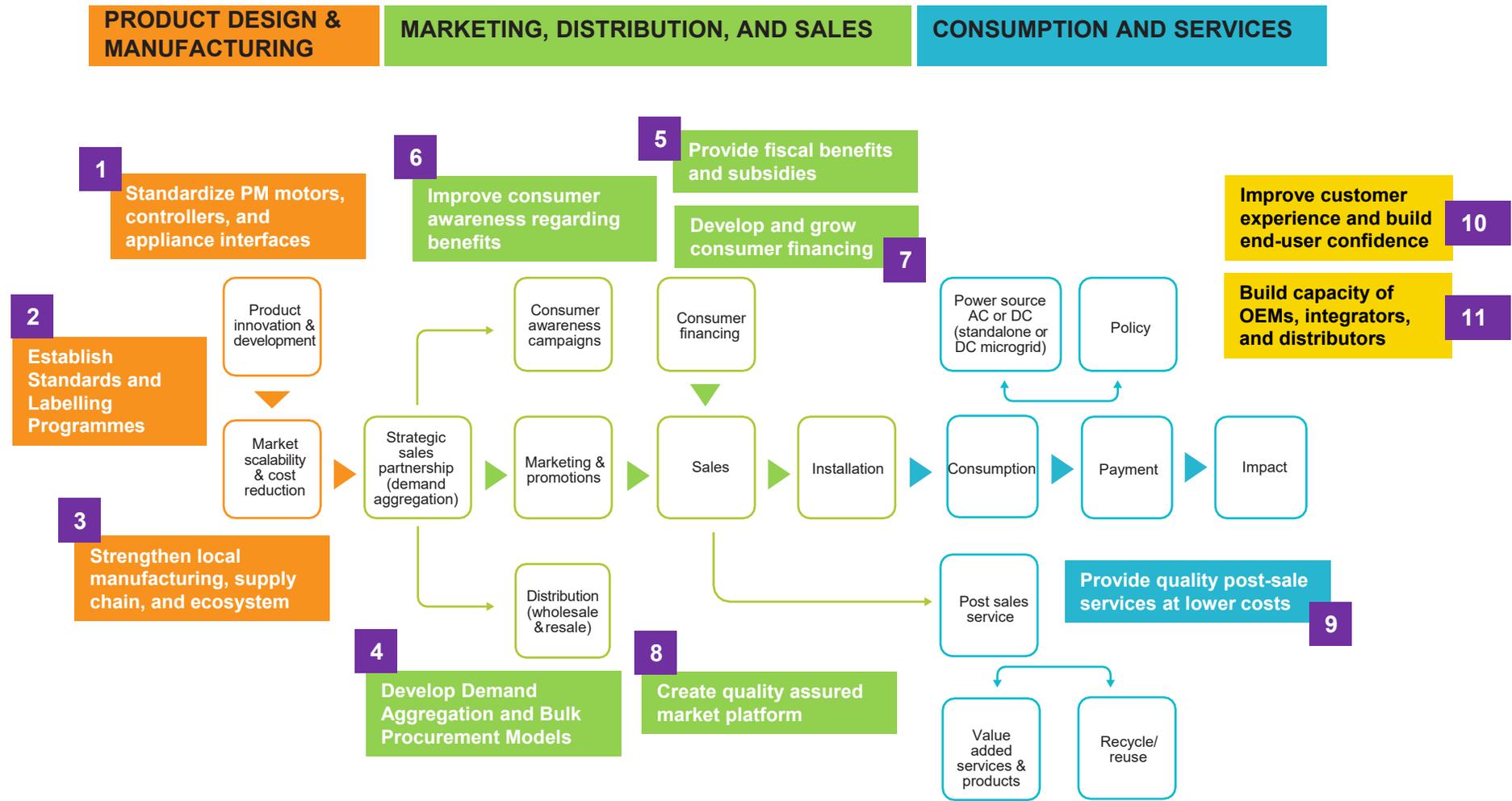


# **Barriers and Strategies to PM Motor Adoption | South Asia and SSA**

# Barriers to PM motor adoption

Category	Barriers	South Asia	Sub-Saharan Africa
Supply Side	High unit economics/ cost	Highly Relevant	Highly Relevant
	Product performance gaps	Highly Relevant	Highly Relevant
	Lack of access to finance (working capital and retail consumer financing)	Not Relevant	Highly Relevant
Customer Side	Low awareness	Not Relevant	Highly Relevant
	Low priority for EE	Somewhat Relevant	Highly Relevant
Policy Side	Lack of purchase incentives	Highly Relevant	Highly Relevant
	Lack of performance standards	Not Relevant	Highly Relevant
	Lack of mass media driven consumer information	Somewhat Relevant	Highly Relevant

# Strategies to accelerate PM Motor Adoption



# Contact

**Rahul Bagdia**

**Managing Director, pManifold**

rahul.bagdia@pmanifold.com

www.pmanifold.com



pManifold is **Energy & Utilities** focused **Strategic Research** and **Consulting** company that is enabling Smart and Clean Tech Markets development and growth in 1) Energy 2) Low Voltage DC (LVDC) 3) Solar 4) E- Mobility 5) Enviro 6) Urban sectors. It is helping industries and organisations innovate and transform their solutions, services, and business model, for faster reforms, higher customer experience, and profitable market growth.

# Contact

**Dr (Eng.) Evan Murimi**

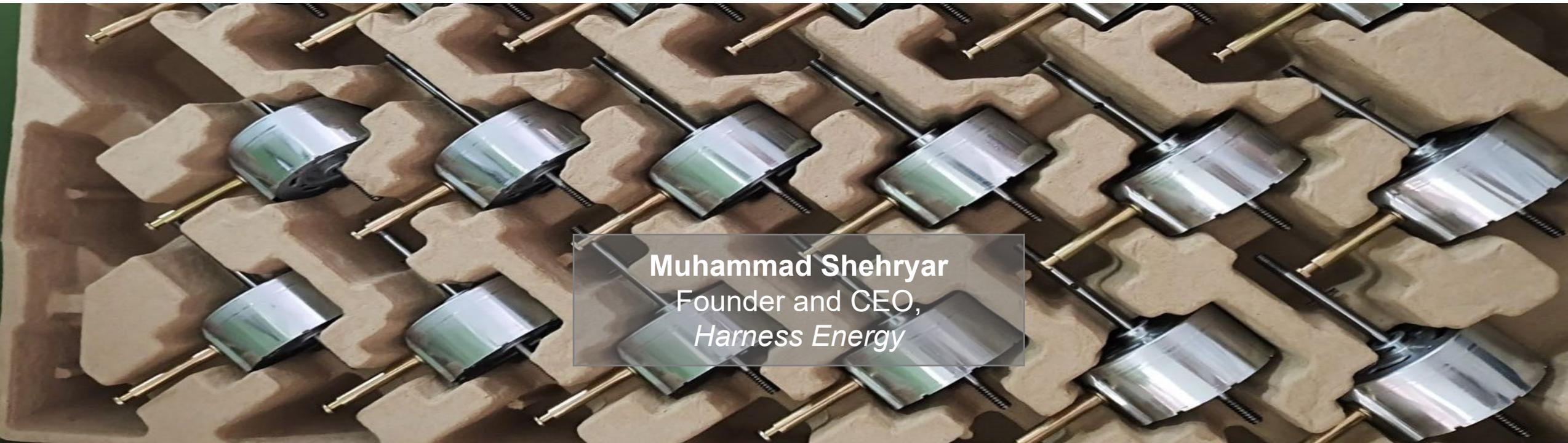
**Energy Specialist and Lecturer**

Jomo Kenyatta University of Agriculture and Technology, Kenya

murimev@gmail.com

Dr Evan Murimi is an Energy Specialist, Researcher, and Lecturer with many years of experience in Energy Access matters in Sub-Saharan Africa. His experience and interests are in rural electrification, off-grid solutions, as well as energy efficiency and demand side management.

# The Case for Permanent Magnet Motors in Fans



**Muhammad Shehryar**  
Founder and CEO,  
*Harness Energy*

# Harness Energy: Who we are

- Founded in 2016
- Distributor of high-quality solar-products and efficient dc appliances
- Innovative business model, esp. financing options
- Off/bad grid energy experts
- Winner of EforA Cooling Call R&D project



# The problems with brushed motors

- High surge current
- Frequent repairs
- Noisy
- Unstable performance
- Very inefficient
- Bad interoperability



# BLDC motors in stand fans

- ~~High surge current~~
- ✓ No surge current
- ~~Frequent repairs~~
- ✓ Very long life
- ~~Noisy~~
- ✓ 30db vs 50-70db
- ~~Unstable performance~~
- ✓ Very reliable due to control
- ~~Very inefficient~~
- ✓ 20-50% more efficient
- ~~Bad interoperability~~
- ✓ Can be used with virtually any SHS and battery



# Should customers pay a premium on bldc fans?



## Behaviour change around

- Warranties
- One-time expenditure
- Much more efficient
- Ideal for rural energy access

	Fan 1	Fan 2	Fan 3	Fan 4
Power	20W	23W	26W	21W
Air flow (CMM)	38	71	62	66
Price	\$22	\$29	\$27	\$27

# EforA Cooling Call project

- Developing Pakistan’s 1<sup>st</sup> bldc motor solar fan
- Improve efficiency without compromising on air flow
- Multiple input options
- Inbuilt LED and 5V USB port



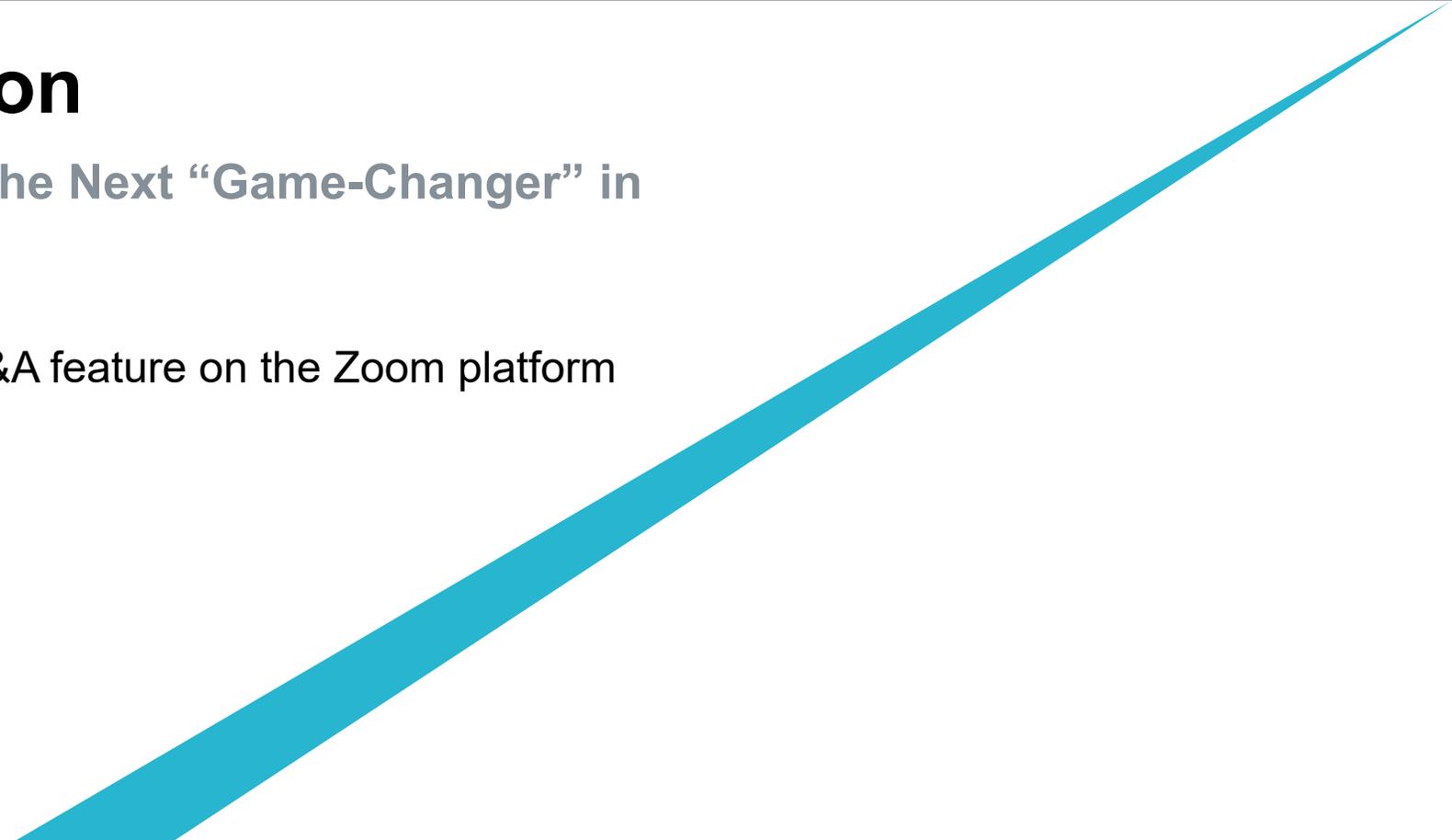
Total Air Delivery (m <sup>3</sup> /min)		66.42204	
Service Value		3.16	
Measured Input Power (Watt)	21	Noise (dB)	34 dB
Measured Input Current (Amp)	1.8	Full Speed (RPM)	1157
Measured Power factor (COSe)	N.A	2 <sup>nd</sup> Speed	N.W
Calculated Power	21.6	3 <sup>rd</sup> Speed	N.W
Calculated Air Delivery (Ft <sup>3</sup> /min)	2345.67079	Inductance (Henry)	N.M*
Measured Starting Current (A)	N.A	Total Resistance of Winding (Ω)	N.M
Measured Running Current (A)	N.A	Temperature Rise test	N.M

---

## **Moderated discussion**

Are Permanent Magnet Motors the Next “Game-Changer” in Energy Access?

Please submit all questions via the Q&A feature on the Zoom platform



# Thank you!

## Thank you for joining our webinar today!

Please share your feedback on the webinar by responding to a short poll.

### Stay in touch



[@EforA\\_Coalition](https://twitter.com/EforA_Coalition)



[@Efficiency for Access](https://www.linkedin.com/company/efficiencyforaccess)



[Read our blog](#)



[Subscribe to our newsletter](#)



[efficiencyforaccess.org](https://efficiencyforaccess.org)



**EFFICIENCY  
FOR  
ACCESS**