From Here to 2050

The Bright Future for Permanent Magnets

Notes to accompany slide presentation

Steve Constantinides
Presented at the UK Magnetic Society's
31st Ewing Event: The Future's so Bright… Potential Trends in Magnetics
Manchester, United Kingdom, November 28, 2018

Slide-1

Magnets are ubiquitous – we find them embedded in devices everywhere: at home, at work, even in the car. What does the future hold in store for permanent magnet usage?

Slide-2

- When asked by Alastair if I might speak about the future for permanent magnets, I was quite interested.
- But as I considered what was entailed, it became evident that forecasting to year 2050 is very different than predicting 3 to 5 years in the future.
- It was at that point the task at hand became daunting.
- But let us focus on what we do know and project forward as best we can.

Slide-3

- It should be possible to forecast market developments by looking at:
    1. What is available from a materials standpoint, that is material supply "push" and
    2. Demands for devices and appliances which benefit from permanent magnets or market "pull".
- Let's examine both aspects concurrently.

Slide-4

- Over the next few decades there are fundamental needs of humanity that will be affected and in some predictable ways.
- For example, there is a growing shortage of potable water and desalinization is a demonstrated method for converting sea water to potable water. The scale of this need will grow dramatically as populations grow and demands on quality water for agriculture increase.
- Numerous technological developments will also have an impact on raw material demands and device component manufacturing.

Slide-5

- A major driver for production is demographics.
- Global population is continuing to grow – more rapidly in underdeveloped countries – the so-called "emerging markets".
- Population will continue to put pressure on resources, enforcing efficiency.
- The predicted global increase in population between 2015 and 2050 is 32%.

- At the same time standards of living are improving.
- The result is a dramatic increase in demand for products: food, clothing, electric power, transportation, etc.

Slide-6

- There will also be pressure on land development for residential, recreation, retail, small business and industry.

Slide-7

- 9 of the 30 most populous cities of the world are in China!
- Contrast Shanghai with 3x the population of London (or New York).
- Population density forces building up rather than out.

Slide-8

- In addition to building up, some facilities are being included at the tops of buildings rather than taking up space on the ground.
- The Raffles City Center in Chongqing is one example.

Slide-9

- Another example is the Dubai Pearl where the top floors connect several buildings while providing retail, restaurant, meeting, and recreational space.

Slide-10

- The Marina Bay Sands Hotel (and Casino) is another example of top-floor usage including an “infinity pool” with a dramatic overlook.

Slide-11

- High density building can become dystopian. But with good planning, it can be attractive and productive as in these “green” examples.

Slide-12

- London’s Strata Tower is one of two existing structures that incorporates wind power generation.

Slide-13

- Urban crowding also creates problems with transportation that have sometimes been solved creatively such as in these two examples:
    - Roads on tops of buildings
    - Trains traveling through buildings – not just under them.

Slide-14

- Whether due to limited land space or bragging rights of the builders, several new sky scrapers are astonishingly tall.
- The Suzhou Zhongnan Center is to be 2,392 feet tall (729 metres). That’s just under half a mile high (0.73 km)!
- Note that it is to have 93 elevators.

Slide-15

- New buildings can also be “fun”.
- These two offer very different approaches to visual appeal.

Slide-16

- What do all these building have to do with permanent magnets?
- Here we list a few of the applications.
- HVAC: instead of small residential or apartment air conditioners, these big buildings use centralized cooling systems with large air fans and duct damper systems.
- Tall buildings require that water be pumped to upper floors.
- We’ve already noted that tall buildings can have numerous, electrically driven elevators.
- And these buildings include large numbers of remotely controlled mechanisms and latches many of which use magnets as sensors or in the actuators.

Slide-17

- Transportation is also expected to change dramatically.
- One change is the increased usage of EV drive systems – for cars and small trucks but also for trains, planes and ships.
- Congested roads will lead to greater dependence on public transportation.

Slide-18

- In this International Energy Agency (iea) forecast internal combustion engines (ICE) are expected to decline to less than 50% of drive systems by 2050.
- (Hybrid drives have both an engine and an electric motor).
- Each drive type has advantages and shortcomings, so all are expected to continue as a fraction of the market.

Slide-19

- Toyota offers this graphic indicating type of drive based on vehicle size and range requirement.
- Gasoline and diesel have a huge advantage in that those fuels have a greater energy density than alternatives.
- Incorporation of hydrogen fuel cell technology has a major hurdle to overcome regarding the lack of a fuel distribution infrastructure.
- Batteries to power large and heavy transport trucks over long distances are too big and expensive. Therefore, fuel cells may be the better alternative.

Slide-20

- The battery is an issue.
    - Adequate raw materials
    - High power density requirement
    - Ability to deliver power as-needed

    - Battery life
    - Cost!!

- Tesla's first vehicles used lithium ion batteries with a cost of ~$15,000.
- For the model S, Tesla estimated it needed to reduce the battery cost to less than $5,000 for the vehicle to be price competitive.
- Battery cost has declined, but pressure on raw materials, especially cobalt, is a continuing issue.
- In 2017, over half the cobalt consumed globally went into batteries.

Slide-21

- Both China and France have made strong commitments to converting from liquid fuels to electric powered vehicles.
- Other countries are likewise pressuring change through mandates and incentives.
- What are the ramifications of a shift from gas and diesel to electric power?
- For magnets, we can estimate the effect as indicated in this table.
- I've made assumptions and you should feel free to adjust the assumptions based on your knowledge and your understanding of how the market is changing.

Slide-22

- Still early in development are aircraft for personal transportation – dubbed flying cars.
- Be the first in your neighborhood to fly to work ☺
- We'll watch this one with great interest.

Slide-23

- All these electric vehicles will require electric power generation and distribution.
- What are the power generating options and which use permanent magnets?
- Wind power represents the greatest opportunity for PM usage.

Slide-24

- According to the Global Wind Energy Council, annual installations will peak at about 125 GW per year around 2040.

Slide-25

- My estimate is for a peak in annual installations somewhat earlier - in the early 2030s.
- With a design life of 20 years, generators will require "repowering" starting in the mid 2020s.
- In summary, I expect peak magnet usage around year 2030 with a gradual tapering to 2050.

Slide-26

- A major consumer of neodymium iron boron has been the hard disk drive industry (and optical drives to a more limited extent).
- In units produced (and sold), the peak year was 2010 at ~630 million drives.
- The number produced annually has declined due to:

    - Slowing in sales of desktop and laptop computers
    - Increased storage per HDD
    - Increasing use of solid state memory (SSD)
- The use of HDDs in server applications is helping to maintain volumes through the early 2020s.
- Longer term, the lower power consumption and cooling requirements of SSDs is expected to increase their market penetration.

Slide-27

- The magnetocaloric effect has been understood since the early 1900s but it took the discovery of the giant magnetocaloric effect (GMCE) to offer the potential for commercialization of cooling devices for consumer use.
- There are two major drivers for a conversion to MCE cooling systems:
    - They are expected to be between 20 and 35% more efficient
    - Do not use Freon refrigerants (which represent an environmental problem)
- What is the market opportunity?

Slide-28

- Cooling is about:
    1. Refrigeration and
    2. Air conditioning.
- The few market segments for which we show data are indicative of the overall size of the opportunity.
- The reward for success has engaged the interest of numerous organizations, business entities and large producers.
- Demonstration units have been produced.

Slide-29

- The technology requires exposing the magnetocaloric material (MCM) to a large magnetic field – the greater, the better.
- About 1.5 Tesla is adequate with the MCM materials in development.
- The material must alternately be exposed to and removed from the magnetic field.
- There are advantages to moving the magnet, not the MCM.
- The illustration at the left exemplifies one of the problems: the amount of magnet material required to generate a high field over a large enough region and gap.

Slide-30

- Since the technology is not fully developed, we must make many assumptions including the required magnet weight used in different applications.
- Feel free to substitute your assumptions in the calculations.
- Needless to say, the overall magnet demand could be very large.

Slide-31

- Assuming partial market penetration of the various new technologies, along with growth of existing ones, magnet use through 2050 is crudely estimated as shown here.

Slide-32

- This is the basis for totals shown on the previous slide.
- 2017 data is reasonably accurate, but 2050 data is truly only a guide – a “guesstimate”.

Slide-33

- Thank you for your attention.
- With this I welcome any questions – or comments if someone would like to contribute to the discussion.