Heat, energy and diverse ways of thinking

By John Bruun and Dawn Watson, July 2020

Today, the energy needs we face have become almost daily news. Where too much fossil fuel is burnt – the excess CO2 released through that is giving us climatic problems. This is because with the suns natural heating of the earth, the portion that enters the atmosphere and then is emitted back into space has become reduced due to internal atmospheric insulation caused by this excess CO2. It takes decades for this energy and heat to be re-equilibrated across the land, sea and atmosphere, and this ends up as permanent raising of the global temperature. Just a few degrees will mean catastrophe for us all. The climate crisis revolves around how to mitigate and stop (!) this burning of fossil fuel. The global call for *net zero carbon* burning aims to set this excess CO2 release to zero and so to mitigate this risk. The technology solutions behind this concept bring us to the heart of the physics of energy production and use. Our Nuclear energy sector is built from our understanding of atomic physics and the science of heavy metals. The Nuclear sector provides an alternate to fossil fuel energy route that can help with achieving net zero carbon.

It helps this conversation to remind ourselves why nuclear is useful? These heavy metals at an atomic level have hundreds of neutrons, protons and electrons in each atom. So much so that each atom is actually unstable and they eventually split, or are broken apart by parts of other atoms, and then form smaller atoms. Each time such an atom splits, then heat is produced. Nuclear physics over the last century has precisely established the unique spitting or time decay signature for these atoms giving a precise emission of heat upon decay. Perhaps more fundamentally to our conversation here, one gram of uranium 235 (one such heavy metal) holds about 3×10^{21} atoms. With the advanced engineering capacity developed in the Nuclear power station facilities we have established a sustained way to carefully control the decay. This provides us scope to obtain large amounts of heat. As a comparator, globally we currently burn about 8 billion tonnes of coal and Nuclear reactors, producing about 10% of global electricity are using about 60,000 tonnes of Uranium, so less than $1/1000$th of a percent by weight. Nuclear material decays – and its associated radiation is invisible, highly toxic and uncontained can poison large areas for centuries so radioactive waste management is a major technology aspect of using this energy source. Nuclear metal technology in a differing form can be triggered into a critical thermal cascade and explosive material and so forms defence technology and physics roles. With the climate crisis – it is now evident that the fossil fuel burning approach to energy production is also a controversial technology that is having long term catastrophic consequences for global society. It seems evident now that a net zero carbon future includes the use of a safe nuclear technology with a close look at how we recognize, confront and negotiate boundaries in our global society. People are at the centre of this specific technology solution. With this in mind, we (Dawn and John) discussed the career and skills that present in the nuclear sector during the July 2020 lockdown. A high technology sector encompass radiation safety and steady heat production. Due to this it's also a large physics related employment area and so provides many inclusive job and long term career roles. These energy careers were the discussion point in 2020 during our second lock down with of a week of IOP lunchtime webinars, where experts from across the UK Nuclear sector discussed the role and career themes in the nuclear technology sector. You can find the full range of talks we hosted at: *Career and skills opportunities for physicists in the nuclear sector* (July 2020 Lunchtime IOP webinar week):

Diversity in a National Laboratory by Dr Lindsay Edmiston (Head of Capability, Waste Management and decommissioning; National Nuclear Laboratory).

Our Sellafield legacy – the original Northern powerhouse by Dr Rebecca Weston (Chief Operating Officer, Sellafield Ltd).

Fan the fire by Sam King (Head of Technical Strategy, RWM Ltd).

Powering the low-carbon future by Jennifer Liley (Project Engineer, EDF-Energy).

Diversity in defence, by Dr Lauren Hobbs (Physics Operations at AWE).

and the recordings are available for IOP members.

The essence of these conversations all revolved around career and opportunity that widened diversity of thinking involve. Please do look through the webinar recordings. From these conversations, the key phase "*diversity of thought comes from enabling a diversity of people message"* emerged. Our impression from this was that shared energy sector thinking opportunity that is emerging from the nuclear sector. This clarity of thinking provides better understanding about physical phenomena and solutions to questions we have in society in general. This, we can see, is a very helpful input to the thinking around the environmental sciences net zero carbon solutions arena.

We thought the framing by Lauren helps to summarise some of the key points of the webinar event. Lauren talked about the vision and long-term career opportunity of physics based careers in the nuclear defence sector, the inclusive and key theme for that sector she pointed out

was: "*we need a diversity of thought and we get this through the diversity of our people*" and "*It makes sense for business and it makes sense morally and ethically*". Careers in this industry sector are geared to multiple technical and/or management themes. She remarked that you may enter based on physics or a physics based background, however you can take it into multiple directions, there is a large scope for agile development focussed around role and personal scientific preference. The focus on inclusive values is high in this sector: the next 15 years will see a projected 80% turnover of staff with 40% eligible for retirement over the next decade. Inclusive biases (such as gender wage inequality) is a feature that is being addressed proactively, by recognising that people in protected characteristic groups face a range of obstacles to career progression. Often the solutions to these are not uniform within each protected characteristic group. The enabling of this inclusive transformation – whilst hard to confront prevailing cultural biases – needs the clear endorsement of people at the top for the changes to progress with clarity and fairness. Lauren remarked that she was lucky as her parents inspired her vision to pursue a career in physics, and she didn't experience the early gender barriers to entry to this profession as she studied at a girl's high school. Being a visible role model, Lauren remarked, are really important to help people see a wider range of professionally active people. It helps to pull people up with you in a form of mentoring role. Also be prepared to say no to this visibility when you don't have bandwidth – the emotional burden can also be demanding, choosing carefully is important. John's overall remarks with Lauren, from the point of view of being a climate physicist was that the clarity of thinking around diversity of ideas being confronted in the nuclear sector is something that is of importance to take on board in the environment sector. The diversity of ideas concept, we can see helps net zero carbon goals, as well as our inclusive framing in general for physics based careers.

How do we approach the energy and diversity changes we are faced with so swiftly? We can learn something very important from the nuclear industry, the level of sophisticated technology of this level of power and potential toxicity requires a highly skilled and sustained workforce. Employment parity is at the heart of this. The answer to our global climate issue is not simply to switch energy sources. We clearly need to substantially reduce our addiction to almost 'unlimited heat'. Fossil fuel combustion based heat is something; it has become apparent, that we should have tackled decades ago. We are living with the raised equilibrated temperature effect already now from what has been extracted and burnt over the last 50 years. A combination of Nuclear and renewable energy are zero carbon at the point of production. A circular economy evaluation will show us that both fossil fuel and nuclear have long-term risks and benefits. For Nuclear, it is something like: *will waste be maintained and safe in 100 years as political systems come and go?* For fossil fuel: *are we now going to be faced with run-away warming climate change and the end of civilization, as we know it?* As society deliberates the energy choices, one aspect is very clear - employment parity and active career path choices that include STEM and Physics technology capability is at the heart of the solutions. We also suggest that good collaborative working practices across the energy sectors is going to help.

Article authors:

> Dr John T Bruun (Lecturer in Mathematics, University of Exeter and Chair of IOP Physics Communicators Group and member of Women in Physics Group) and
>
> Dawn Watson (Head of Strategy & Technical, Analytical Services, Sellafield Ltd and Group officer of IOP Women in Physics Group and Nuclear Industry Group).

The July 2020 lunchtime webinar series was also co-hosted/organised by:

> Heather Beaumont (Head of Profession for Physics, Waste and Environment, Jacobs & Chair IOP Nuclear Industry Group) and
>
> Lucy Bailey (Head of Research Support Office, RWM Ltd & IOP Nuclear Industry Group).

and the article authors.