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# Urgent Need for the Establishment of the International Institute for Sustainable Technology in South-East Europe

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## Abstract

*In our interdependent and fast changing world, every individual's future depends on the wellbeing of all humanity. Transformative out-of-the-box thinking is urgently required, especially in South-East Europe, which occupies a unique position in the world. Historically, it has been the crossroads of cultures and civilizations. Its strategic geographic location has placed it at the centre of significant socio-political actions. It is on a major migratory route that could alter the demographic and economic structures of not only the region but also the rest of the world. The region that was once home to reputed centres of education now faces an intellectual vacuum and a significant decrease in skills, particularly technological skills. This sensitive SEE area urgently requires the establishment of centres of scientific excellence within the next 5-10 years. The most current challenges we face require science along with original thinking, creativity and action to eliminate the ignorance that leads to existential risks and to support achievement of the UN 2030 Agenda. Today knowledge is the most dominant power for social change. Employed properly, it also has the potential for being the most democratic source of power as a great equalizer for people and countries. The political decision to establish centres in SEE, with focus on physical and life sciences research as well as human resource development, needs to be made. These centres must involve the scientific community worldwide. International involvement provides greater scientific impact. It facilitates technology transfer, improves all forms of communications and establishes cultural understanding. International scientific cooperation can be the precursor to cooperation on other fronts as well.*

## 1. The Need for Urgency

We live in one of the best times in history.[*,†] Yet, our world is not sustainable; it is economically, socially and politically vulnerable and self-destructive.[1] The Bulletin of the Atomic Scientists decided on January 25, 2018 to place the Doomsday Clock at 2 minutes to midnight—the worst ever scenario[‡] since 1953 when the testing of hydrogen bombs both by the USA and the USSR implied that the world could be destroyed by war, terror or human error. The dangers and threats have now multiplied: in addition to military conflicts, we are

* The German weekly 'Der Spiegel' published a series of articles under the title "In the old days everything was worse". The figure published on October 16, 2016 shows a significant reduction in global poverty from 1820 when over 90% of population lived in poverty; in 1970 the percentage was reduced to 60% and in 2015 to less than 10%. In absolute numbers, 1.022 billion in 1820, 2.218 billion in 1970 and 706 million persons lived in poverty in 2015.

† Ivo Šlaus, 'Transforming Our World', to be published

‡ Bulletin of the Atomic Scientists, it is two minutes to Midnight, January 25, 2018

threatening our only home—Earth: not only with climate change but also through the sixth biological extinction and pollution; we use the equivalent of the capacities of two earths. The wealthiest countries' ecological footprint is 200 times more than the poorest ones'.

Humankind is aware of the dangers, threats and the need to act. On September 25, 2015, the UN General Assembly unanimously approved the UN Agenda 2030—the Sustainable Development Goals, appropriately called 'Transform Our World!' Nobel laureates meeting in 2000 stated: "It is time to turn our backs on the unilateral search for security, in which we seek to shelter behind walls. Instead, we must persist in the quest for united action to counter both global warming and a weaponized world. …**To survive in the world we have transformed *(and are transforming)*, we must learn to think in a new way *(out-of-the-box thinking and acting)*. As never before, the future of each depends on the good of all.**"

Various activities evolve at different time scales. For instance, synthetic biology and Information and Communications Technology (ICT) have been evolving much faster than shipbuilding did. In addition, different countries evolve at different speeds. These time scales—the speed of change—constantly change. In a global, interdependent and fast changing world, the shortest time scale is the most critical and it is about 10 years. **Therefore, our actions have to be urgent!**

## 2. Why South-East Europe?

Politics is very difficult and naturally one pays attention to problems that seem to be imminent. North Korea and the Middle East appear now to be the most demanding problems. We tend to associate terrorism just with the Middle East, ignoring extremism in our midst.

South-East Europe (SEE) has been at the center (ancient Greece is the source of our science, democracy, logic and philosophy), the crossroads of cultures and civilizations (Franks and Byzantine Empire, Ottoman Empire and Europe, crusades, Habsburgs and Romanovs) and at the periphery. Throughout its history it has produced remarkable cultures, e.g. Vučedol and Vinča, geniuses and emperors, and it initiated major socio-political actions, sometimes just because it was at the periphery.

Though a major conflict occurred within SEE 20 to 30 years ago, SEE is still a major vulnerable area that can erupt and dangerously reverberate globally. It is the most important unfinished job of the European unification process. Seven countries in SEE are still not members of the EU, and each enlargement creates at least mild frictions. SEE has among the lowest employment rates in the world. All socio-economic and political indicators place the SEE countries at the bottom of Europe.

Europe is characterized by a low fertility rate. Within a few decades the indigenous population of SEE countries will decrease by about 10-20%. In addition to low fertility rate, the SEE has appreciable difference in fertility rates among different ethnic groups, thereby changing ethnic compositions. SEE is a major migratory route and within the next few decades, about a hundred million people will cross this area. The demographic and economic structures of the SEE have been aggravating the already vulnerable socio-political conditions.

*Sustaining Growth*, a report of The European Bank for Reconstruction and Development (EBRD), lists various socio-economic indicators (Table 1).

*Table 1: Indicators Assessing Socio-economic Progress*
(Source: EBRD Report 'Sustaining Growth' 2017)

| Country | Competitiveness | Good Governance | Ecological Approach | Resilience | Total |
|---|---|---|---|---|---|
| Germany | 8.43 | 8.66 | 7.39 | 8.41 | **8.06** |
| Slovenia | 6.93 | 5.74 | 6.67 | 7.44 | **6.90** |
| Poland | 6.38 | 6.15 | 6.27 | 6.65 | **6.64** |
| Hungary | 6.42 | 5.31 | 6.37 | 6.65 | **6.49** |
| Croatia | 5.75 | 5.14 | 6.03 | 6.61 | **6.07** |
| Bulgaria | 5.96 | 4.69 | 5.82 | 6.54 | **5.87** |
| Montenegro | 4.89 | 5.12 | 5.15 | 5.93 | **5.38** |
| Serbia | 4.94 | 4.39 | 5.77 | 5.55 | **5.37** |

A serious threat stems from inequality. The ratio of the wealthiest 20% of the population to the poorest 20% is 3.6 in Slovenia, 5.0 in Croatia, 8.0 in Bulgaria and 10.0 in Serbia.

Indicators assessing political (DEM), structural (RoL—Rule of Law) and economic progress (ECON) for the 27 countries in transition in Central and South-East Europe and in the Commonwealth of Independent States in 2001 are summarized in Table 2 (smaller value signifies better result).

*Table 2: Indicators Assessing Political (DEM), Structural (RoL—Rule of Law) and Economic Progress (ECON)*

| Country | DEM | RoL | ECON |
|---|---|---|---|
| Poland | 1.44 | 1.88 | 1.67 |
| Hungary | 1.94 | 2.5 | 1.92 |
| Slovenia | 1.94 | 1.75 | 2.08 |
| Croatia | 3.25 | 4.13 | 3.58 |
| Serbia+MN | 4.63 | 5.88 | 5.33 |
| Macedonia | 3.75 | 4.63 | 4.58 |

The area that is home to academies, schools and universities does not have a single high-ranking university within Emerging Europe and Central Asia's top 30 universities. During the last 50 years the scientific activities in SEE countries have relatively decreased, thereby creating an intellectual vacuum in the most sensitive area—in the Mediterranean encounter of Africa, Asia and Europe. The beauty of SEE has encouraged tourism but there is a significant decrease in skills, notably in technological skills. **Therefore, it is necessary to establish a center of scientific excellence in SEE.**

Our contemporary world is interdependent and any adverse fluctuation within SEE will influence the entire global world. Similarly, lack of action has grave consequences. The unsuccessful proposal to locate International Thermo-nuclear Experimental Reactor (ITER) in former Yugoslavia is an example. Yugoslavia was an excellent country—neutral, non-aligned and positioned close to the heart of Europe and close to Asia and Africa—to host a major international endeavor crucial for developing fusion energy. Though the proposal went to the level of the Prime Minister and Presidency of Yugoslavia, and most of them supported it, it was drowned by meaningless political activities. More than 20 years were lost in fusion research and the country suffered war and aggression. This was the failure of domestic and also international politics, giving reality to the warning by Axel Oxenstierna: "Behold, my son, with how much stupidity is world politics done."

*"The existential risks facing humankind are mainly caused by our ignorance."*

*"A necessary condition of all life is interdependence: everything relates to everything else; nothing exists in isolation."*

Socio-economic and political indicators of most of the countries in transition change appreciably and erratically (Table 1 and 2). **It follows that any meaningful action to influence SEE countries has to be accomplished within the next 5-10 years.**

## 3. Why Science?

The salient features of our contemporary world—fast changing, interdependent and global—are all generated by science. Succesfully facing most current challenges requires science, creativity and out-of-the-box thinking and action. The existential risks facing humankind are mainly caused by our ignorance. The realization of the UN Agenda 2030 demands research across all scientific disciplines: multi-, inter- and trans-disciplinary.

All major cultures developed science and scientific research is deeply rooted in each culture. Scientific research enriches each culture. Science is the best way to develop culture and in addition—since science is universal, international, cumulative and objective—it links itself with all other cultures and nations.

Furthermore, science is a self-correcting system. It is cooperative and at the same time encourages originality, independence and dissent. It stresses the need for an open mind; time and again the scientists must reverse direction, and they normally do. Proven scientific positions have often been proved wrong no matter how original. Interpretations of experimental data and observations, explanations of events and paradigms have had alternative rationalizations and have always been limited, never complete. This helps scientists tolerate ambiguity, strive for improvement and allow for self-correction. Science teaches us the value of relatedness. A necessary condition of all life is interdependence: everything relates to everything else; nothing exists in isolation. Hence everything gets its essence via its interactions with something else. Science, therefore, seeks not only truth, but also relatedness which is embedded within various domains. One branch of science relates to and in various degrees is embedded into another. Out of this implicit coupling of the parts of science emerges the underlined unity among its seemingly chaotic functions. The mutual embeddedness of the parts of science allows for their integration, feedback and accommodation. Science is changing, it is becoming more complex. Large international projects like the Intergovernmental Panel on Climate Change, the human genome, the International Thermonuclear Experimental Reactor, the European Organization for Nuclear Research, the large "user" facilities (e.g., particle accelerators), the big data facilities for medicine and knowledge being generated in cyber space, are examples of this trend. Even the character and culture of today's large-scale research at major research facilities have been changing.

Presently knowledge is the most dominant political power. It is inexhaustible. It is the most democratic source of power. Science and Technology breakthroughs act as equalizers creating a chance for resetting to zero economic and political advantages accumulated in some centers. *However significant science and technology are, they are of little use without concomitant socio-economic inputs and appropriate political drive*.

## 4. Development and Research Excellence

Global competitiveness and Summary Innovation Indicators are strongly correlated with Research Excellence Score (RES), as defined by the OECD Oslo Manual. This suggests that RES, which measures the quality of the R&D potential, could be a reliable indicator for assessing the effectiveness of the R&D potential in achieving social and economic goals.

Research Excellence Score (RES) is defined by four indicators: HICIT—top 10% of the most highly cited publications/total number of publications, PACPAT—high quality patent/million inhabitants, TOPINST—number of world class universities and institutes/GNERD, and ERC—number of high prestige grants/public GNERD. Table 3 summarizes Research Excellence Score for several countries.

*Table 3: Composite Score of Research Excellence*

| Country | Overall Score | HICIT | TOPIN | PCTPAT | ERC |
|---|---|---|---|---|---|
| Germany | 62.8 | 69 | 44 | 69 | 73 |
| Hungary | 31.9 | 39 | 20 | 17 | 82 |
| Slovenia | 27.5 | 48 | 10 | 25 | 48 |
| Croatia | 12.2 | 17 | 10 | 13 | 10 |
| Latvia | 11.5 | 14 | 10 | 12 | 10 |
| Turkey | 13.8 | 32 | 10 | 11 | 10 |
| Greece | 35.3 | 57 | 27 | 13 | 79 |

SEE countries were at the very bottom on the Composite Research Excellence Score for 2005 and 2010. In addition, they almost did not progress in those five years, as opposed to the Netherlands, Denmark, Sweden, Germany and Norway which have demonstrated significant progress. Countries with the highest Research Excellence Score are Switzerland, the Netherlands, Denmark, Sweden and Israel, while Latvia, Croatia, Turkey, Lithuania, Slovakia, Romania and Malta have the lowest.

Publications that by citations ranked in the top 1% of 'Highly Cited Papers' for the period from 2014 to 2017 for several countries are listed below.

*Table 4: Publications that by citations ranked in the top 1% of 'Highly Cited Papers'*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| USA | 2644 | Slovenia | 4 | Hungary | 3 | Germany | 297 |
| UK | 542 | Serbia | 4 | Croatia | 1 | Greece | 15 |
| China | 249 ('17) | Slovakia | 1 | Romania | 2 | Bulgaria | 1 |

Even EU27 is just at the 2% level, and all SEE countries rank quite low in the RES compared to the ratio of the public and business R&D Expenditure to GDP. The scatter among RES and public and business R&D expenditure indicates that Gross National Expenditure for R&D (GNERD) is not necessarily a good indicator for the R&D activity.

The R&D potential consists of human power, science-technology infrastructure, organization of R&D, creative capacity, efficiency (measuring R&D activity vs. Science and technology: number of publications, impact factors, highly cited papers, number of patents) and effectiveness (accomplishing pursued socio-economic objectives). One can distinguish among input (number of scientists, number of engineers, number of technicians, GNERD) and output indicators (number of authors publishing in the Web of Science journals ρ(W) and the four Research Excellence Scores: HICIT, TOPIN, PCTPAT and ERC. Any indicator is subject to uncertainties. The largest uncertainties are in the number of scientists and engineers (**±20%**) and in the GNERD/GDP (about 15% of governmental budget is 'lost' and so this indicator also carries a large uncertainty of ±20%). Output indicators are much more accurate: number of authors publishing in WoS journals has uncertainties of ±10% and highly cited papers, top institutes/universities of ±5%. Different accuracies of indicators stem from the fact that input indicators are compiled from various nation-state sources plagued often by somewhat different definitions. On the contrary, output indicators are based on several international assessments, thereby considerably reducing uncertainties. A basic question that needs to be answered is: 'can the measurement of top performance give a meaningful assessment of the entire R&D system?' The answer is in the fact that the relationship between indicators is described by the Matthew's effect 'to those that have, will be given more', or equivalently by the cumulative advantage distribution characterized by Lotka's law: $P(n) \sim 1/n^2$, where P(n) is the number of authors that published 'n' publications. **Therefore, identifying research excellence provides a good assessment of the entire R&D system.**

The relationship between input and output R&D indicators measures the efficiency of the R&D potential. There has been an impressive increase in the Gross National Expenditure on R&D (GNERD) in China from 4.6% to 20% and it is significant that it has been followed by a similar increase in highly cited papers: from 2.6% to 1.9%. The importance of these R&D indicators is best summarized by Maria Zuber, NSB Chair and Vice President for Research, of the Massachusetts Institute of Technology. "*This year's report shows a trend that the U.S. still leads by many S&T measures, but that our lead is decreasing in certain areas that are important to our country....That trend raises concerns about impacts on our economy and workforce, and has implications for our national security. From gene editing to artificial intelligence, scientific advancements come with inherent risks. And it is critical that we stay at the forefront of science to mitigate those risks*."

The US is still the undisputed leader in GNERD, but will not remain in that position for long. Last year, the US spent $496 billion on research and development, while also attracting $70 billion in private investment. China spent $408 billion and attracted $34 billion worth of venture capital in 2016. However, since the year 2000, China has been increasing its R&D expenditure by a staggering 18% a year while the US witnessed just a 4% annual increase. At this rate, it will not take long for China to invest more than any other country in R&D. In addition, between 2000 and 2014, the number of people graduating with a bachelor's degree in science in China had risen from 359,000 to 1.65 million, compared to 483,000 to 742,000 in the US. In other words, China is on the cusp of becoming the undisputed king of science and technology. China is becoming a role model of R&D activity and productivity!

Measuring effectiveness is much more complex. The general relationship between R&D input indicators and specific socio-economic results is described by an S-type curve. The features of this relationship are: a) There is a threshold. The R&D potential below the threshold cannot accomplish socio-economic tasks. M.M. Qureshi formulated the Development Capability Index (DCI) as

$$DCI = (GDP/c)^{0.45} \text{ x } (GDP)^{0.55} = (R\&D \text{ potential})^{0.45} \text{ x } (GDP)^{0.55} = (\rho(W))^{0.45} \text{ x } (GDP)^{0.55}$$

The essential step is linking GDP/c with the R&D potential and consequently with the number of authors publishing in WoS journals. b) The threshold is given by the following: **ρ(W) = 100 - 200/million inhabitants, GNERD/GDP = 0.8 -1.0% and number of scientists and engineers, technicians = 300-500/million inhabitants.**

**The R&D potential of the SEE countries is around the threshold and therefore, the essential political goal of these countries and also of the EU is to strengthen the R&D potential of each SEE country so that specific socio-economic objectives can be achieved.** We need to clarify three issues at this outset.

First, is the above expression which links DCI and the number of authors publishing in WoS journals reliable? An analysis of Lamy's High Level Group comparing the EU and the USA shows that growth in the EU is larger in all scientific activities, but the EU lags behind the USA in the number of patents and in the value added growth of business economy in high-tech sectors. This seems to contradict the result that Research Excellence leads to prosperity. Interaction between science, technology, market and prosperity is complex. V. Bush in his famous report advocated the science-push model. A few decades later, partly stimulated by the phenomenon described above which is particularly notable in the UK, the market-pull model was proposed. Actually, interaction evolves in bundles of streams synergistically synthesizing basic research and innovation.

Second, the increasing cost of more and more basic research leads decision makers to suggest setting priorities in a nation's research. While certainly one has to judiciously select among various major experimental facilities, it is necessary to appreciate that even the largest international facilities such as ITER cost less than 0.01% of the world GDP, and as rightly said by Erich Vogt, director of TRIUMF, "*Major experimental facilities today are an expression of our worldview and of our culture as pyramids and cathedrals were centuries ago, and how much of the GDP was devoted to them*." Though it is frequently said that the beginning of the 20$^{th}$ century was determined by breakthroughs in physics and the mid-20$^{th}$ by breakthroughs in biology, we are most likely approaching a time when major breakthroughs will develop in economics and political sciences. This will be characterized by a unity of scientific endeavor—consilience. New technologies always end up becoming social activities. All scientific disciplines have to be developed and this underlines the essential role of universities and academies which need to be intertwined with research centers.

Third, the dilemma: the science-push vs. market-pull debate is sometimes erroneously translated as curiosity-driven vs. applied research. This dilemma is easily resolved by realizing the most curiosity-driven research: x-rays are now the most applied technology, and an attempt to improve the antenna and cleaning birds' excreta finally signalled the birth of our universe. Development of instruments has been a milestone in the history of science.

## 5. Why International, Why Global?

Throughout our history centers of excellence have always been international attractors and consequently many, often most researchers, professors and students working at these centers have been foreigners. For example, this was so during the Tang dynasty in China, at the University of Paris during the Middle Ages and so it is today. A question we should ask is: is it beneficial and if so, in what way?

Clearly, international co-publications have a greater scientific impact. They have multiple other benefits: facilitating technology transfer, improving all forms of communications and establishing cultural understanding. There is no doubt that international scientific cooperation was at the core of second-track diplomacy as is the case of the Pugwash Movement, and it was the basis of very successful international endeavors such as the Intergovernmental Panel on Climate Change.

Therefore scientific centers of excellence have to be international centers.

## 6. Case Study: The Ruđer Bošković Institute

To contemplate establishment of an international center of excellence in SEE, it is instructive to analyze the foundation and development of an institute that was established almost 70 years ago in Zagreb. Immediately after the end of World War II, Yugoslavia established three nuclear institutes: Vinča near Belgrade in 1948, Jožef Stefan Institute in Ljubljana in 1949 and Rudjer Bošković Institute in Zagreb in 1950. Scientists leading these institutes were internationally well-known: Pavle Savić was the collaborator of Irène Joliot-Curie and Frédéric Joliot-Curie, Anton Peterlin later worked at TU München and at Research Triangle Park, N.C. and Ivan Supek collaborated with Heisenberg and later was the founder of the Yugoslav Pugwash Movement and the InterUniversity Center, Dubrovnik. Excellence and international dimension continued to be the essential feature of all three institutes and they are all internationally well-known and several of their professors taught and were researchers at some of the world's best universities. The Nuclear Energy Institute in Bulgaria was founded in Sofia in 1972. The Ruđer Bošković Institute (RBI) was conceived as a nuclear institute with emphasis on nuclear sciences, but it quickly included theoretical physics, solid state physics, physical chemistry, organic chemistry, biology and electronics. During the late 1960s, marine research developed and RBI included an old research institute founded by the Berlin Academy at the end of the $19^{th}$ century in Rovinj.

Scientometric studies demonstrate that in the period 1960-1975, the scientific productivity of Tito-ruled Yugoslavian scientists was comparable to that of scientists from Austria, Finland, Czechoslovakia, Hungary and Poland. During 1975-1990 it was behind, comparable to Bulgaria, Greece, Ireland, Portugal and Romania. The founding of three nuclear institutes in Yugoslavia has to be certainly credited for this success. Table 5 compares numbers of WoS publications during three periods: 1976-1990, 1991-2004 and 2005-2016 published by scientists from the Ruđer Bošković Institute with the number of papers published by all scientists of Croatia and the number of papers published by scientists working in natural and life sciences and in engineering.

*Table 5: Number of WoS Publications*

| **Period** | **IRB** | **Croatia (nat+engi)** | | **Croatia (all)** | |
|---|---|---|---|---|---|
| 1976-1990 | 2.671 | 6.214 | **43%** | 7.487 | **28%** |
| 1991-2004 | 3.947 | 11.822 | **33%** | 16.309 | **24%** |
| 2005-2016 | 5.845 | 20.210 | **29%** | 40.749 | **14%** |

It is clear that the establishment of the Ruđer Bošković Institute (RBI) gave an impulse to scientific activity and scientific productivity of Croatia. Later, many scientists from the Institute went to universities in Croatia and some continued their career abroad. (Percentages of papers by scientists from RBI with respect to the corresponding total number are in bold.)

Basic features of the three nuclear institutes in Yugoslavia were international cooperation, inter-, multi- and trans-disciplinarity and a large degree of flexibility. Naturally, these features varied among the three institutes. We will now focus on the RBI and mainly on physics since the discussion concerning establishing the SEE International Institute for Sustainable Development is now concentrated on two proposals dealing with synchrotron and hadron radiotherapy. Two features characterize the development of the RBI. One, from the very beginning, the promotion of physicists was based on international evaluations. Gradually this extended to all disciplines in the RBI. Two, besides full-time employees, RBI opened its facility to scientists from other institutions who worked part-time.

Development of a center of excellence requires concentration on frontline research in certain niches where relative advantage can be found. Physicists from the RBI concentrated on five niches:

1. Few particle studies. The first international conference was held in London in 1959, the next one was held on the Adriatic coast in Brela in 1967, and then a series of international conferences was established every two-three years. Mostly, physicists from RBI were organizers or speakers, e.g. in Los Angeles in 1972, in Santos in 2006, and the Caen conference in 2018. In addition, they were among the initiators of the European Few Particle Community. European conferences were regularly held and the late 1980s saw the collaboration of physicists from RBI, Tübingen and Bochum. The first successful study of the neutron-neutron force was done in Zagreb in 1961, and it led to additional data as to where it would be possible to determine the difference between the masses of the up and down quarks, thereby providing information on charge symmetry breaking. Few particle studies involved extensive international collaborations with UCLA, Rice University, Los Alamos National Laboratory, Naval Research Laboratory, Georgetown University, Duke University, Kyoto University, IKO Amsterdam, Louvain-la-Neuve, Hokkaido University, North Carolina Central University and Vinča Institute. Few nucleon studies were based on the use of the 0.2 MeV Cockcroft-Walton accelerator used as a source of 14 MeV neutrons, on a counter, a 3-dimensional analyzer and on international collaboration with theoretical physicists from the USA, Germany, India, Japan, USSR and later with experimentalists from the USA, the Netherlands, Germany and Belgium. **Within about 6-7 years (1956-1962/3) the group of physicists from the RBI became internationally well-known.** In addition to particle research, fast neutron physics and nuclear reaction mechanism studies achieved international recognition.
2. Radiopharmaceuticals. By the early 1950s, local industry was capable of building a 15 MeV cyclotron. Construction started in 1953, and Tito opened the cyclotron in 1962. Unfortunately, it was impossible to extract the beam and only after accelerating the negative ions could the deuteron beams be extracted in 1972. However, the internal beam was quite adequate to produce radiopharmaceuticals and to initiate studies on neutron radiotherapy. During 1975-1983, $^{67}$Ga and $^{81m}$Kr were regularly produced and delivered to hospitals throughout Yugoslavia and Austria. In addition, a mathematical model for lung ventilation was developed. During this time RBI was the largest producer of these two radiopharmaceuticals together with Hammersmith Hospital in the UK. The paper on the use of cyclotron in neutron radiotherapy is still one of the most widely read papers. **It took radiopharmaceuticals about 25 years from 1955 to 1980 to achieve international recognition.**

*Table 6: Scientific Productivity in Physics and Medical Science*

| | **Articles in Physics** | | **Articles in Medical Science (NSF-Science Indicators)** | |
|---|---|---|---|---|
| | 1997 | 2011 | 1997 | 2011 |
| World | 84,021 | 108,551 | 144,819 | 182,772 |
| Austria | 483 | 598 | 1,437 | 1,515 |
| BG | 226 | 127 | 67 | 58 |
| Slovenia | 116 | 216 | 91 | 176 |
| UK | 4,661 | 4,321 | 13,410 | 12,282 |
| HR | 77 | 104.5 | 115 | 192 |
| Serbia | | 175 | | 194 |
| Montenegro | | 3.5 | | |
| Macedonia | 7.7 | 14.9 | 5.7 | 9.5 |
| *(fractional credit for authorship)* | | | | |

3. Computer-constructive visual art was developed between 1968 and 1974 by several electronic engineers led by Vladimir Bonačić working in the nuclear physics lab. ‘New Tendencies’ were part of a broader European post-informel art movement which included famous Croatian artists, e.g. Ivan Picelj and sculptor Vojin Bakić. The group led by Bonačić extended their activities in Israel and Germany and some of their work are in museums in Zagreb and Karlsruhe.
4. A group of physicists from RBI founded the ‘Interdisciplinary Frontline Research Center’ in 1985 involving scientists from the Academy and the University of Zagreb. Among its most notable activities were: a) endeavor to locate ITER in Yugoslavia (current project DONES—part of ITER—will most likely be located in Spain, but Croatia will be the prime collaborator); b) including ex-patriots in the Yugoslav R&D program. It was estimated that Diaspora represents about 30% of the national R&D potential; c) establishing Yugoslav Association for the Advancement of Science; d) active participation in the UNESCO ‘Reconstruction of Scientific Cooperation in SEE’ (1999-2001); e) proposal to establish SEE International Institute for Technology (2003) and f) support to establish the South-East European Division (SEED) of the World Academy of Art and Science (WAAS Fellowship increased from about 15 to over 100).
5. The R. Bošković Institute was founded by a group of professors from the University of Zagreb and the close relationship between the RBI and higher education is a noteworthy feature. Throughout the history of the Institute it has secured the best human resources. Several young researchers from RBI got their PhD with co-mentors from outstanding universities: University of Rochester, MIT and UCLA. The RBI was part of the University of Zagreb for about 10 years in 1980s and during that time several M.Sc. and PhD degrees were awarded.

The essential feature of all these niches was the development of human-resources. It started in 1946 through the seminar on theoretical physics.

## 7. Conclusion: Plan of Action

Three centers of excellence—The Extreme Light Infrastructure (ELI) —were recently established in Bucharest, Szeged and Prague. The southern SEE countries—from Slovenia and Croatia to Bulgaria and Turkey—have no comparable major centers of excellence. Our analysis clearly demonstrates the imperative to establish a center of excellence, actually at least two centers in southern SEE, one in the West and one in the eastern part of the southern SEE.

Such a center should be focused on sustainable technology to contribute toward the realization of the Sustainable Development Goals—the UN Agenda 2030. From our analysis, particularly the case study of the RBI, it seems that the essential features of these centers of excellence should be multi-, inter- and trans-disciplinary, having a strong connection with higher education and education in general, and since the salient characteristics of the contemporary world are changing fast, it is desirable that the center is flexible. **The establishment of such a center is urgent. It implies that within at most 10 years the center has to be internationally recognized as a center of global excellence.**

It is necessary that the majority of scientists and technicians working in the Institute are local, and by local I mean citizens from SEE countries. Majority means about 60-65% for the first 10 years after which the institute would gradually become more international, but there must always be at least 30-40% local scientists and technicians. Administrative staff have to be kept to a minimum and they do not have to be local. The emphasis on inter- and transdisciplinarity as well as experiences at RBI and elsewhere suggest that it would be advantageous if a fair number of researchers are physicists: about 35-40%. All studies on the future of work stress that employment in all fields, including research, should be flexible, and insist on maximum human capital maintenance and development.

Essential and necessary steps to take are:

1. Identify pillars,
2. Develop human resources and
3. Assure appropriate political drive: both nations and EU should include international action, and secure adequate financial support.

The pillars could be existing nuclear institutes in Slovenia, Croatia, Serbia and Bulgaria, universities, academies, or the noteworthy: The Inter-university Center (IUC) and The International Centre for Sustainable Development of Energy, Water and Environment Systems (SDEWES).

IUC was established in Dubrovnik more than 40 years ago at the initiative of Ivan Supek, then rector of the University of Zagreb, who proposed it at the conference of the International Association of Universities in Montreal in 1970. It includes over 100 universities throughout the world. Courses, seminars and conferences are regularly organized and IUC is one of the centers of WAAS. The IUC is led by an international board and chairs of the Council and the Executive Board members are scientists from abroad. There were 598 courses and 266 international conferences with 38,881 participants during 1971-1991, and in 2011 there were 45 courses and 11 international conferences with 1,416 participants.

SDEWES is a series of international conferences aimed at promoting and pointing out the need for sustainable development. SDEWES is also a WAAS center. The first conference was organized in 2002, and so far 12 conferences in Dubrovnik, Piran, Ohrid and Rio de Janeiro and on a cruiser have been organized with about 200-500 participants, with 450 papers and about 100 posters per conference, many published in scientific journals and also in their own journal JSDEWES.

Development of human resources should proceed in a three-pronged way. First, joint degrees (essentially Ph.D.) and joint permanent education systems should be established in collaboration with outstanding universities throughout the world. It is interesting that the Zagreb School of Economics and Management, a mono-disciplinary private university, has initiated a joint PhD program with the Sheffield Hallam University, UK. During Tito's rule in Yugoslavia, the University of Zagreb attracted thousands of foreign students. Unfortunately, this number is now much smaller. Second, frontline research should be encouraged and concentration on certain niches based on the pillars outlined above should be emphasized. Strong support should be given to CERIC-ERIC (Central European Research Infrastructure Consortium) which includes centres in Trieste, Ljubljana, Krakow, Prague, Budapest, Zagreb, Belgrade and Bucharest. Due to fast changes with a characteristic time of about or less than 10 years, there should be some diversity among these niches. One example of an outstanding project is DONES and all support should be given to assure its full development. Third, development of human resources across scientific disciplines is necessary, education should become innovative at all levels and systems must be established to develop the right instruments.

The Lisbon Strategy for growth and competitiveness agreed on March 23-24, 2000, defined a strategic goal that the EU should become in the next decade the most competitive and dynamic knowledge-based economy in the world. Obviously, more time is needed and certainly the 'vacuum' in the southern SEE countries has to be quickly corrected. How much financial investment is required and through whom and how should it be provided? It is clear that a major EU endeavor is needed! A well-defined political decision and directive are necessary, including proper financial support. Financial support can come from the EU, from international sources (e.g. IAEA), from national and private sources. Experience with private and even private-public funding has not been very good so far. For instance, a private medical center 'Medicol' in Zagreb is using the building where the RBI cyclotron was located. A small cyclotron is being used to produce F-FDG, but there is absolutely no research. It is an entirely commercial activity with focused medical application. International sources can currently provide only a small fraction of financial help, so financial support has to be assured from the EU and national sources, with some possible support from interested major economies of the world. Starting with the investment in ELI (each about €400 million, to be followed e.g. in Romania by the center on Danube with about €200 million and an ICT center requiring €100 million) one can conclude that a €200-400 million investment should be made for the founding of the South-East European International Institute for Sustainable Technology. **All of this should come from the EU while costs towards the continuous maintenance of the institute should be borne by the host country. This would help them reach the necessary 3% level of the GNERD/GDP.** For instance, the GDP of Croatia is about 40G€ and assuming 3% of GDP is allocated to GNERD, it amounts to 1.2G€. A reasonable fraction of about 25% would suffice for maintenance of the SEEIIST.

At a recent conference in Trieste, two alternative types of facilities for the SEEIIST were outlined: synchrotron and hadron radiotherapy. Bulgaria declared its interest in hadron radiotherapy. Since for western SEE countries facilities in Trieste and other cities in Austria and Italy as well as CERN are much more convenient, it can hardly be justified that they would be focused on using facilities in eastern SEE and/or build a facility similar to those that already exist in Italy and Austria. It seems that it would be strategically appropriate to contemplate a center in the western SEE focused on sustainable technologies (where SDEWES is ideal), linked with education (and IUC is appropriate), sea, marine and habitat research (there are centers along the Adriatic), sustainable energy sources including energy storage and related robotics. **Clearly, such a centre could be established and it could reach international recognition within the next 6-10 years.**

**In summary:**

- **Step 1:** Clear political decision to establish two centers in southern SEE: one focused on SDEWES, sea, marine, habitat research, sustainable energy sources including energy storage and related robotics, on IUC in western SEE, and another on hadron radiotherapy in Bulgaria. Decisions about appropriate funding from individual countries and from the EU should be quickly and wisely made.
- **Step 2:** Human resources development should emphasize joint degrees and simultaneously, support for CERIC-ERIC and DONES endeavors.

**The existing Western Balkans Research and Innovation Strategy Exercise (WISE) could be intertwined with both steps.**

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