零碳天空：可持续航空燃料改变未来

太古股份有限公司

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摘要

气候变化是全球共同关注的议题。习近平主席提出的 2060 年实现碳中和的目标，体现了中国政府在这一问题上的大国担当。应对气候变化是一个系统性问题，需采取有力、快速和协同的行动，需要公共政策制定者和企业公民的共同努力。太古集团成立于 1816 年，是一家业务高度多元化的大型跨国企业集团，分为地产、航空、饮料及食物链、海洋服务和贸易及实业五大范畴。太古集团作为可持续发展理念的坚定支持者和践行者，制定了清晰的集团可持续发展策略 SwireTHRIVE 来应对气候变化、减碳、水资源保护和减少废弃物等重要的环境问题。

太古集团已扎根中国 155 年，业务集中于香港和中国内地，一直致力于为中国的高质量发展贡献价值。李克强总理在 2021 年政府工作报告中表示将制定 2030 年前碳排放达峰行动方案。太古希望能为行动方案的制定贡献商界智慧，以我们的经验和研究为制定有关行动方案提供参考。我们的研究表明，发展可持续航空燃料对于航空业的减排以及中国实现 2060 年碳中和

目标具有重要意义。本文将以旗下国泰航空多年来在减碳方面的探索经验为据，阐释航空业在减碳领域面临的独特挑战，并借鉴国际经验对实现航空业的零碳发展提出建议。

作为全球领先的航空公司之一，国泰航空在过去数十年中采取了各种举措来减轻其对气候变化的影响，包括不断提高燃油效率，使用碳抵消以及开拓可持续航空燃料。在 2020 年，国泰航空再进一步承诺于 2050 年实现净零碳排放量目标。考虑到现有技术提升燃油效率的作用已经达到瓶颈，而碳抵消和碳交易等市场机制仅能在中短期发挥有限效果，进一步提升基建和运营并探索飞机设计方面革命性的更新十分重要。但航空业零碳发展目标的实现在很大程度上建基于可持续航空燃料的大规模应用。

展望未来，中国将成为世界上最大的民航市场。在中国从航空大国迈向航空强国的道路上，中国的可持续发展战略选择对全球航空业举足轻重。作为重要的制造业和物流大国，中国航空运输在促进货物流动、直接投资和人员交流方面发挥着至关重要的作用。随着预期航空活动及排放量的大幅度增长，中国需要找到一种有效的航空减碳解决方案，以展示其应对气候变化的决心。

同时，全球可持续航空燃料市场每年的潜在价值超过 6400 亿元人民币也为中国以行业领先地位占据国际市场提供机会。考虑到可持续航空燃料的应

用是不可避免的发展趋势，中国可提前布局，培育国内产能，完善供应链建设，确保实现可持续航空燃料能源自主，并分散对化石航空燃料的依赖。航空企业也可管控原油价格波动的风险、降低碳征费带来的财务压力。此外，可持续航空燃料亦可以促进城市固体废物，农业废物或废食用油等废料为原料的循环经济，通过绿色经济刺激不同地区的就业增长。

目前，全球可持续航空燃料的生产仍处于起步阶段，其数量远低于航空燃料总需求的 1%。中国在可持续航空燃料的生产和应用领域早已掌握了关键技术，并早在 2011 年就成功进行了可持续航空燃料试飞。但其可持续航空燃料的使用主要在于测试和一次性飞行，目前并无任何长期生产或使用可持续航空燃料的公开承诺。政策环境对可持续航空燃料开发及应用具有重大影响。由于目前可持续航空燃料生产成本较高，因此它须依靠政策的辅助来缩小价格差距，以与化石燃料竞争，直到能够扩大生产规模并降低成本。不同国家针对可持续航空燃料制定的不同政策导致了不同的采用率。中国政府可在需求端和供应端同时采取激励措施，形成良性循环，并借鉴国际上行之有效的可持续航空燃料联盟模式，在粤港澳大湾区寻找试点机场，鼓励从该机场出发的航班长期使用可持续航空燃料，并在粤港澳大湾区发展可持续航空燃料产业链，之后可将试点经验推广全国，在研发、生产和应用可持续航空燃料方面努力成为世界领导者。

正文

气候变化是全球共同关注的议题。《巴黎协定》设定了目标，把全球平均气温升幅控制在工业革命前水平以上低于 2℃之内，并努力将气温升幅限制在 1.5℃之内。习近平主席宣布，中国的二氧化碳排放力争于 2030 年前达到峰值，并争取 2060 年前实现碳中和，体现了中国政府在这一问题上的大国担当。应对气候变化是一个系统性问题，需采取有力、快速和协同的行动，需要公共政策制定者和企业公民的共同努力。太古集团成立于 1816 年，是一家业务高度多元化的大型跨国企业集团，分为地产、航空、饮料及食物链、海洋服务和贸易及实业五大范畴。太古集团已扎根中国 155 年，业务集中于香港和中国内地，并一直致力于为中国的高质量发展贡献价值。作为可持续发展理念的坚定支持者和践行者，制定了清晰的集团可持续发展策略 SwireTHRIVE 来应对气候变化、减碳、水资源保护和减少废弃物等重要的环境问题。例如，集团旗下太古地产和太古可口可乐均在科学研究的基础上提出了减碳目标，并获得科学基础目标倡议组织（SBTi）的认证。这些目标不仅包括在自身运营中大幅减少碳排放，还包括联合供应商和客户共同努力实现全链条减碳。两家公司均参与了“1.5° C 的商业抱负”[1]，为 2021 年 11 月召开的国际气候大会所倡导的走向零碳经济之路提供助力。

[1] https://unglobalcompact.org/take-action/events/climate-action-summit-2019/business-ambition

然而，太古集团总排放量中占比超过九成的是航空板块。作为全球领先的航空公司之一，国泰航空在过去数十年中采取了各种举措来减轻其对气候变化的影响，包括不断提高燃油效率，使用碳抵消以及开拓可持续航空燃料。在 2020 年，国泰航空再进一步承诺于 2050 年实现净零碳排放量目标。这一目标的实现在很大程度上建基于可持续航空燃料的应用。本文将阐释航空业在减碳方面面临的独特挑战，发展可持续航空燃料对于航空业的减碳行动以及中国实现 2060 年碳中和目标的重要意义，并借鉴国际经验对未来发展提出建议。李克强总理在 2021 年政府报告中表示将制定 2030 年前碳排放达峰行动方案，我们认为，可持续航空燃料是碳达峰行动中不可或缺的部分，希望能够以我们的经验和研究为制定有关行动方案提供参考。

一、航空业的减碳行动面临的独特挑战

在全球温室气体排放份额中，虽然航空业的碳排放只占人为排放的 2%，但仍然引起了许多关注和争议。主要原因是航空业在实际减少碳排放方面，面临着独特的挑战。

1、航空业发展的必然趋势

自二十世纪五十年代起，全球航空业不断高速发展，载客量累计增长数百倍。[2] 随着技术进步和经济发展，越来越多的人能享受航空旅行带来的机

[2] https://www.icao.int/sustainability/pages/facts-figures_worldeconomydata.aspx

遇，如出国留学、拜访亲友以及实地体验不同的地方和文化等，而非像过去一样，只有超级富豪和精英阶层才能乘坐飞机。全球航空业也将随着经济发展而持续增长。

此外，航空运输也是一种不可替代的运输方式。对于拥有庞大网络的中国而言，高铁是一种有效的解决方案，可替代某些短途航班。然而，全球约80%的航空碳排放量都来自1500公里以上的长途航班，许多长途航班都涉及跨海或洲际飞行。到目前为止，尚无可满足这一需求的替代交通运输方式。

考虑到航空业可以持续为经济和社会发展带来的重要贡献，航空业的发展不应为应对气候变化而停滞。但它必须以可持续的方式增长，以确保能够应对气候变化带来的挑战并福泽后代。

2、现有技术的局限性

从现代喷气机时代开始，航空业已经大幅提高其运营燃料效率。自二十世纪五十年代起，有赖于内燃机技术和飞机总体设计的技术进步，飞机单座耗油量降低了 80%以上。目前，现有技术的提升基本上到达了平稳期。虽然仍有改进的余地，但调整幅度较小，无法实现航空业所需的大幅度减排目标。

航空业界在替代能源方面进行了大量的探索，例如电动飞机或氢动力飞机方面的研究。去年，空中客车公司发布了开发氢动力飞机的计划，预计在2035年投入商业运营，这在市场上引起了巨大的轰动。但这类飞机仍有很多

局限性。例如，上述飞机的航程仍不足以满足洲际飞行需求，载客量亦只有宽体客机的一半，在商业角度较为不利。而飞机使用周期通常有30-40年。除非新型替代能源飞机能自2030年起满足航空业的需求，大规模投入商业运营，否则基本上没有足够时间利用这一方法，实现中国2060年的碳中和目标。

3、碳抵消及减排交易计划的有限效果

世界各地有很多地方都将碳抵消或减排交易计划作为抑制航空业碳排放增长的工具。自2012年起，欧盟已将航空业纳入其减排交易计划，涵盖了欧盟境内的所有航班。国际航空碳抵消和减排计划（CORSIA）是一个全球性计划，由国际民航组织（ICAO）制定，旨在限制国际航空的二氧化碳净排放量，以便从2020年起实现碳中和增长的目标。[3]

虽然这些计划可作为抑制航空业碳排放量增长的阶段性措施，但其本身并不能实现飞行减排，且随着飞行需求的增加，碳排放会有实质的增长。因此，在需求持续增长而现有措施难以实现实质性减排的情况下，预计到2050年，全球航空业的人为二氧化碳排放份额会从2%增至3%。

二、可持续航空燃料是现阶段实现航空业碳中和的最佳选择

1、什么是可持续航空燃料

[3] 由于新冠疫情的影响，因此CORSIA试验阶段用了2019年的数据。

可持续航空燃料是航空业用于描述非常规航空燃料，即非化石衍生燃料的主要术语。之前比较普遍的说法是“生物航空燃料”，但目前人们更喜欢使用可持续航空燃料这一术语，原因是它更能准确地描述这种非常规燃料的特性。“生物燃料”通常是利用生物资源（植物或动物材料）生产的燃料。然而，目前的技术允许利用城市固体废物或工业生产过程中排放的废气等其他非生物资源去生产燃料。此外，为了有效使用“可持续”这一术语，生产的燃料须符合某些可持续性标准，如生命周期碳减排水平、与食品生产不存在竞争性关系等。可持续生物材料圆桌会议（RSB）等政府间组织将达成可持续性标准。

相对于化石燃料，可持续航空燃料可在整个生命周期内减少二氧化碳排放，某些减排率可高达 80%。以植物制成的可持续航空燃料为例，植物在生长过程中吸收的二氧化碳，基本上相当于燃料在飞机内燃机内燃烧时产生的二氧化碳的总量。然而，在可持续航空燃料的生产过程中，从作物生长所需的设备、原材料运输和燃料提炼等过程中会产生排放，不能达至完全碳中和。

2、可持续航空燃料的特性

可持续航空燃料是通过混合常规煤油（化石燃料）和可再生碳氢化合物而制成的。这些燃料可认证为“A1 航空燃料”，且可在不对飞机或航空燃料供应基础设施作出任何修改的情况下安全使用。可持续航空燃料可以与一般

航空燃料安全地以不同比例混合，直到最高混合限值。具有上述特性的燃料称为“即用型燃料”，这一特性能够使人们广泛且快速地将可持续航空燃料用于现有设备和基础设施，但前提是可持续航空燃料的产量足够大。

3、可持续航空燃料的技术可及性

可持续航空燃料的生产必须是一个受监管的过程，以确保燃料质量符合其用途和安全使用目的。目前，国际标准组织ASTM批准了七种生产途径。每种途径都有不同的原料要求及生产技术，且具有独特的挑战和效益，如可持续原料的供应是否充足、设备所需的资本投资、加工成本及减排水平等。附录一的列表汇总了到目前为止已经批准的生产途径。目前，有更多生产途径正在开发中，获得批准后可为生产商提供更多的选择。

三、国泰航空公司净零排放的路径

国泰航空一直是业内积极应对气候变化的先驱,并于2020年进一步做出2050年实现零碳净排放的承诺。这是国泰航空可持续发展旅程中的重要一步，凝聚了其在提高燃油效率、碳抵消和可持续航空燃料使用方面的努力。但根据国泰多年来探索的经验，现有技术无法达致零碳未来，国泰的零碳承诺主要建基于可持续航空燃料的大规模应用。

科技发展是减少飞机排放最重要的助力。通过购入更节能的新型飞机和各项营运调整，国泰航空的燃油效率在 1998 年至 2019 年间提高了 20%以

上。国泰航空亦是首间引入自愿性碳抵消计划的亚洲航空公司，以使乘客能够抵消其航班的碳排放量。自 2007 年推出以来，平台已抵消超过 30 万吨二氧化碳。然而这些领域的提升并不足以达成重大的减排目标。

国泰航空很早开始关注可持续航空燃料对达成大量减排的重要性并作出战略投资。2014 年，国泰航空公司成为 Fulcrum BioEnergy 公司的股东及董事会成员，是首家投资该公司的航空公司。Fulcrum 是一家总部位于美国的可持续航空燃料开发公司，也是将城市固体废物转化为可持续航空燃料的全球开发和商业化先驱。自 2016 年起，国泰航空用可持续航空燃料从图卢兹往香港交付了 41 架空中客车 A350 飞机。到目前为止，这项目共使用了超过 200 吨的可持续航空燃料。在这过程中，国泰航空获得了有关使用可持续航空燃料的宝贵经验和知识。

国泰航空承诺，分十年从美国 Fulcrum 工厂购买 110 万公吨的可持续航空燃料，预计从 2024 年起，每年供应相等于 2019 年运营水平总燃料需求约 2%。但这远远不够 ，因为国泰航空有半数航班从香港总部出发，需要建立区内可持续航空燃料的供应链。尽管欧洲和美国已有更多可持续航空燃料供应商投资发展，但中国的供应尚未起飞。未来十年，粤港澳大湾区乃至整个中国内地的可持续航空燃料供应要有显着增长，国泰航空和中国民航业才可能实现零碳排放，为中国在 2060 年达致碳中和奠定基础。

四、可持续航空燃料对中国的战略意义

1、中国民航业减排的重要意义

作为世界第二大民用航空市场，2019 年，中国民航业年收入达到 1 万亿元人民币，运载了超过 6.6 亿人次的旅客和 700 万吨空运货物。[4] 民航业为中国经济做出了重要贡献。作为重要的制造业和物流大国，中国航空运输在促进货物流动、直接投资和人员交流方面发挥着至关重要的作用，为价值超过 9.7 万亿元的外国直接投资及 15.5 万亿元的出口总额作出了直接贡献。[5] 展望未来，航空业将继续在中国经济增长中发挥重要作用。根据国际航空运输协会（IATA）的预测，到本世纪二十年代中期，中国有望成为世界上最大的民航市场。[6] 到 2037 年，旅客人数可能会增加两倍，民航业对国民生产总值的贡献将达到 1.8 万亿元人民币，并为中国提供约 670 万个就业机会。[7]

在中国民航业发展的同时，碳排放增长的现实压力也令人关注。中国民航业每年约排放 1 亿公吨二氧化碳，排放量目前排名世界第二，仅次于美国。目前，中国的人均航空排放量远低于许多国家，约为 0.09 公吨二氧化碳，而美国和英国分别是 0.57 公吨和 0.86 公吨。[8] 中国航空活动和相关排放量有

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4 http://www.xinhuanet.com/english/2020-01/14/c_138704443.htm
5 https://www.iata.org/en/iata-repository/publications/economic-reports/china--value-of-aviation/
6 http://www.xinhuanet.com/english/2020-01/14/c_138704443.htm
7 https://www.iata.org/en/iata-repository/publications/economic-reports/china--value-of-aviation/
8 https://www.carbonbrief.org/emissions-from-chinese-aviation-could-quadruple-by-2050

巨大的增长空间。如果航空旅程的高速增长导致中国的人均排放量增至美国的排放水平，那么其航空排放量会达到 6 亿公吨二氧化碳。随着预期航空活动及排放量的大幅度增长，中国需要找到一种有效的航空减碳解决方案，以展示其应对气候变化的决心。在中国从航空大国迈向航空强国的道路上，中国的可持续发展战略选择对全球航空业举足轻重。

2、国际可持续航空燃料市场机遇

全球航空业早于 2009 年已定下 2050 年大幅度减碳的目标：净二氧化碳排放量与 2005 年相比减少 50％。[9] 由于可用选项有限，可持续航空燃料变得越来越重要，且在航空业减排倡议中占比升高。国际能源机构（IEA）的《温升超过 2°C 的情景》[10]，预计 2060 年全球可持续航空燃料需求会达到每年 1.5 亿公吨。这相当于航空燃料需求总量的 60-70%。

上述需求量预测显示，可持续航空燃料市场每年的潜在价值超过 6400 亿元人民币。可持续航空燃料在未来几十年有巨大的需求量，这为中国以行业领先地位占据国际市场提供了机会。

3、能源安全与风险管控

燃料通常是航空公司最大的单笔运营成本，普遍占三成以上。原油价格

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9 https://www.iata.org/en/programs/environment/climate-change/

10 https://www.iea.org/reports/world-energy-model#scenarios-in-weo-2020

波动会直接影响航空公司的盈利能力。因为成本驱动因素不同，使用可持续航空燃料可为航空公司提供一种遵循不同经济趋势的替代燃料。发展可持续航空燃料也将减低对化石燃料的依赖，分散风险。未来市场预计会有越来越多的碳征费，使用可持续航空燃料亦能因其减排作用而降低相关的财务负担。此外，可持续航空燃料是不可避免的发展趋势，中国可考虑提前布局，在此领域做出长期投入，培育国内产能，完善供应链建设，确保实现可持续航空燃料能源自主。

4、促进循环经济

可持续航空燃料亦可以促进循环经济。多种生产途径涉及使用不同类型的废料，无论这些废料是城市固体废物，农业废物还是废食用油，甚至利用工业废气的途径也可以带来循环经济利益。例如，塑料可以利用工业废气中的“回收碳”来生产，而不是仅仅依靠原始材料或一般回收的塑料。

5、社会和经济效益

可持续航空燃料也有助于通过绿色经济刺激不同地区的就业增长。除了在城市和工业区周围开发可持续航空燃料加工厂外，在农村地区也可产生社会效益。例如，某些区域虽然不适合种植粮食，但可能适合种植可持续航空燃料的原材料，通常在原材料来源附近亦会安装提炼基础设施，从而创造额外的就业机会和经济活动。

五、大规模生产及应用可持续航空燃料所面临的挑战

1、全球的政策、生产及应用现状

政策环境对可持续航空燃料开发及应用具有重大影响。由于目前可持续航空燃料生产成本较高，因此它须依靠政策的辅助来缩小价格差距，以与化石燃料竞争，直到能够扩大生产规模并降低成本。因此，不同国家针对可持续航空燃料制定的政策亦导致不同的采用率。目前，激励措施价值最高的地区是美国西岸和欧洲。相关政策例子请参阅附录二 。

在积极政策的支持下，可持续航空燃料联盟往往会围绕某个主要机场而成立。此等联盟通常牵涉不同行业及组织，例如机场管理局，航空公司，燃料供应商，监管机构甚至地方政府。联盟的目的是让该机场能提供可持续航空燃料供参航空公司的定期航班使用，并加快扩大其使用范围。这些机场都有少量定期航班使用可持续航空燃料 [11]，在全球使用可持续航空燃料范围内处于领先地位，展现了令人鼓舞的发展潜力。

全球可持续航空燃料的生产仍处于起步阶段，其数量远低于航空燃料总需求的 1%。预计供应量将从 2025 年起开始增长，到 2030 年可能达到 300 万公吨。但即使如此，可持续航空燃料的总产量仍处于非常低的水平，占航

[11] 关于可持续航空燃料联盟，荷兰阿姆斯特丹的史基浦机场（AMS）与荷兰皇家航空公司就是一个成功例子。美国西岸的许多机场与其燃料供应商和航空公司也有类似的安排，包括旧金山国际机场（SFO），洛杉矶国际机场（LAX）和西雅图-塔科马国际机场（SEA）。

空燃油总需求的 2%之内。目前，专门从事可持续航空燃料生产的小型新兴公司正主导市场，但是一些生物柴油生产商和传统化石燃料公司也渴望探索发展机会，其中也有一些在市场上相当活跃。目前主要产量来自北美和欧洲，在亚洲包括新加坡，日本和中国也有少量工厂。

2、中国生产及应用现状

中国在可持续航空燃料的生产和应用领域早已掌握了关键技术，并早在 2011 年就成功进行了可持续航空燃料首次试飞。但其使用主要在于测试和一次性飞行，目前并无任何长期生产或使用可持续航空燃料的承诺。

试飞的重要性，体现在向监管机构展示各航空公司使用可持续航空燃料飞行的技术能力，并让中国航空业相信可持续航空燃料是一种安全高效的燃料。在 2013 年 4 月的试飞后，中国民航局向中国石化发出了适航证书，以证明其生产的可持续航空燃料符合必要的质量标准。附录三中提供了在中国使用可持续航空燃料试飞的其他信息。

生物燃料一直是中国减少对进口能源依赖，并帮助保护环境的战略计划的一部分。中国过去的几个五年计划中均有提及。但到目前为止，该战略计划仅注重道路运输燃料，主要是生物乙醇。根据十三五计划，中国制定了到 2020 年实现非化石能源占一次性能源消费比重达 15%的目标。因此，中国目前是全球最大的生物乙醇生产国之一，年产量超过 40 亿升。然而，现计划并

不包括航空用生物燃料。由于中国对可持续航空燃料的关注程度和需求量都不高，因此在中国商业规模生产可持续航空燃料的设备并不多。

六、在中国发展可持续航空燃料的建议

在过去十年，使用可持续航空燃料的航班飞行了数十万次，牢牢地奠定了可持续航空燃料作为一种安全且技术上可行的替代燃料的地位。可持续航空燃料广泛应用的主要障碍不是技术限制，而是经济限制。未广泛采用可持续航空燃料的主要原因是“需求和供给较低”。由于生产量小，成本较高，现阶段的可持续航空燃料比传统燃料贵 2-5 倍，在无任何政策干预的情况下，可持续航空燃料无法与传统化石燃料竞争。供应链带宽也是一个问题。某些类型可持续原料供应不足，而有限的商业规模生产设施，也因为政策要求或政府补贴没有包含可持续航空燃料而投入作道路运输专用生物燃料的生产，可持续航空燃料的发展更见不足。

由于可持续航空燃料开发需要多方合作，投入可观资源，以及需要多年发展，因此，所有利益相关方需制定积极的政策和战略，以提高生产能力。稳定的政策环境对于建立可持续航空燃料供应链而言极其重要。随着 2060 年碳中和目标的制定，中国创建了良好的环境，以支持可持续航空燃料市场得到长期繁荣发展。

许多研究证实，为实现预期结果，一揽子政策干预方法比采用单个干预

方法更有效。中国在新能源汽车市场推广和发展的经验就是政策支持与商业驱动的紧密结合并取得长足进步的最好例证。若政策能够在供给侧和需求侧同时发力，则可形成良性循环。随着需求量的增加，可持续航空燃料供应链将会获得更多投资，从而进一步产生规模经济，降低成本，以便进一步扩大需求。为了确保可持续航空燃料的经济性，至少需在中短期内同时在需求端和供应端采取激励措施：

为了鼓励发展可持续航空燃料供应链，国家和地方政府可考虑通过税收优惠、补贴、贷款、贷款担保或直接供资或公私合营等方式，支持可持续航空燃料研究与开发以及示范工厂的建设，也可以实施其他政策来降低相关工厂的投资风险。例如，对于拥有在其它市场建设并运营可持续航空燃料设施经验的外国公司而言，可提供有利条件，以便将其技术和经验引进中国。此外，可参照中国生物乙醇市场开发的成功经验，考虑制定生产目标。

为了扩大需求，可着力弥补化石航空燃料和可持续航空燃料之间的成本差异。国家或地方政府可考虑引进使用可持续航空燃料的激励措施。通过具有竞争性的定价和额外的环境和声誉效益，航空公司会增加可持续航空燃料的用量，进一步扩大市场需求。另外，当前为地面运输设计的生物燃料激励政策也可以延伸至航空业，或为航空运输引入比地面运输更高的激励机制。

支持可持续航空燃料市场发展的其他政策包括采用全球公认的可持续性

标准，以促进中国生产的可持续航空燃料进入庞大的国际市场。同样，政策制定者还可以鼓励用户使用现有的全球可持续航空燃料会计标准，并积极参与未来的标准修订与完善。

为了加快中国可持续航空燃料的发展，建议在中国选择某些航空枢纽，并建立当地的可持续航空燃料联盟。联盟应由机场、燃油供应商、航空公司和当地政府等主要持份者组成，其共同目标是让从该机场出发的定期航班能够使用可持续航空燃料。然后，可以将这些试验点的经验应用于全国各地。

我们进一步建议将粤港澳大湾区作为此类试点之一。香港特别行政区政府与国泰航空有同一个雄心勃勃的目标，即到 2050 年实现碳中和。香港机场管理局在缓解气候变化的努力方面也一直处于国际领先地位。凭借大湾区的工业发展、资金流动、技术和人才的优势，并在政府的指导和政策支持下，相信国泰航空在可持续航空燃料方面的经验可以帮助大湾区成为中国可持续航空燃料发展的领先区域。

结语

在减少人为温室气体排放的直至零排放的路程上，中国颇具领导者的优势。如此巨大的减排工程需要我们在生活的方方面面做出根本性的改变，包括能源的采集与储存、食品生产、运输、制造、建筑等所有领域。

有利的政策和监管环境对于探索和应用创新科技以达致零碳转型至关重要。太古集团旗下各运营公司均在尝试和应用各种类型的前沿科技以提升效率、节省能源。例如自 2011 年起，太古地产与清华大学合作成立了建筑节能与可持续发展联合研究中心，共同开发和测试提高其物业能效的新方法。太古地产还积极通过采用场址内发电和绿色能源采购的方式，支持向可再生能源的过渡。目前，太古地产的商业项目之一成都远洋太古里和太古可口可乐的云南工厂均实现了 100%使用可再生能源电力。

太古旗下各个业务板块，包括国泰航空、可口可乐、太古地产的共同经验均表明，政府政策的引导与支持对商界实现自身的减碳目标至关重要。政府可考虑从政策上鼓励可再生能源的使用，推广智能电网、储能电池系统以及碳捕获和储存技术，为减碳工程提供更多的技术工具和制度网络，扩大技术创新和渗透，创新融资机制，尤其是为支持净零战略和行动计划而设计的机制。太古扎根中国超过一个半世纪，愿意在中国碳达峰、碳中和的道路上全力以赴，为实现绿水青山、零碳蓝天的可持续发展战略贡献自己的力量。

附录一：ASTM 批准的七种可持续航空燃料生产途径

途径	原料（示例）	批准日期	最高混合限值
费托合成烃煤油组分（FT-SPK）	生物质能（林业残留物、杂草和城市固体废物）	2009	达到 50%
加氢处理酯和脂肪酸（HEFA）	油基生物质能，如亚麻荠油、卡里纳塔油和废油	2011	达到 50%
加氢处理发酵糖-合成异链烷烃（HFS-SIP）	甘蔗、蔗糖	2014	达到 10%
具有芳烃的 FT- SPK（FT-SPK/A）	生物质能（林业残留物、杂草和城市固体废物）	2015	达到 50%
乙醇喷射合成煤油（ATJ-SPK）	农业废物（干草、杂草、林业残留物和稻草）、玉米和甘蔗、工业生产过程中排放的废气	2016	达到 50%
催化水热解法喷气燃	大豆油、麻风果油、茶花油、亚	2020	达到 50%

料（CHJ）	麻荠油和卡里纳塔油		
加氢处理碳氢化合物（HH-SPK）	海藻油	2020	达到 10%

附录二：支持可持续航空燃料相关政策例子

美国可再生燃料标准（RFS）

- RFS 为炼油厂和供应商设定了使用生物燃料的强制性目标-到 2022 年达到 360 亿加仑。此外还为此类可再生燃料生产建立了交易市场，让生产商可以从中获利。

美国加州低碳燃料标准（LCFS）

- LCFS 旨在到 2030 年，将交通运输碳排放强度降低 20%。LCFS 监管燃料供应商，并根据其生产的燃料类型为其提供碳价值。这可以看作是“减碳补贴”的一种形式。

英国可再生运输燃料义务法（RFTO）

- RTFO 的目标是每年提供 45 万公升可持续航空燃料，目标是到 2032 年达到总燃料需求的 12.4%。从废物转化的燃料是法案的优先选择，设有特定的用量目标和双重经济激励。

欧盟可再生能源指令（RED）

- RED 承诺到 2030 年将为包括航空业在内的运输部门提供 14%的可再生燃料。可持续发展航空燃料有 1.2 倍的额外优势，某些类型的废物转化而成的燃料亦可获得 1.2 倍的额外优势。

荷兰运输能源义务法（HBE 信贷）

- HBE 要求公司增加可再生能源在其燃料供应中的份额。航空业可以选择参加以从奖励计划中受益。

附录三 在中国使用可持续航空燃料试飞的信息

日期	航空公司	燃料描述	燃料来源	航班描述
2011 年 10 月 28 日	中国国际航空公司	混合 50%的麻疯果油炟炼的燃料	中国石油	从北京起飞的试飞
2013年4月24日	中国东方航空公司	由棕榈油和废弃食用油炟炼的燃料	中国石化	在上海虹桥机场试飞 1.5 小时
2015年3月21日	海南航空公司	50%由废弃食用油炟炼的可持续航空燃料	中国航空油料集团公司	从上海飞往北京的首个国内客运航班波音 737-800
2016年5月28日	国泰航空有限公司	10%由甘蔗炟炼的可持续航空燃料	道达尔/阿米瑞斯	从图卢兹飞往香港，首次使用可持续航空燃料的调机航班
2017 年 11	海南航空	15%由废弃食用油	中国石化	从北京飞往芝加

月 22 日	公司	煶炼的可持续航空燃料		哥的航班波音 787——使用可持续航空燃料飞行的首个跨海航班
2019年2月28 日	中国东方航空公司	10%由甘蔗煶炼的可持续航空燃料	道达尔	从法国图卢兹飞往广州的新飞机 A320neo 的调机航班

Flight to net zero: How sustainable aviation fuel helps achieve carbon neutrality

Swire Pacific Limited

(March 2021)

Executive Summary

Climate change is one of the most pressing challenges facing our planet and its people. President Xi Jinping declared that China will achieve carbon neutrality by 2060. Responding to climate change is a systemic issue that requires vigorous, rapid, and coordinated action, as well as joint efforts by policymakers and corporate citizens. Established in 1816, the Swire Group is a highly diversified global conglomerate. Swire's five business divisions include Property, Aviation, Beverages & Food Chain, Marine Services and Trading & Industrial. As a firm supporter and longstanding practitioner of sustainable development, Swire has a clear group strategy and action plans under its 'SwireTHRIVE' programme to address significant, material sustainability challenges including climate change and decarbonisation, as well as water conservation and waste reduction.

Swire has been in China for 155 years with our businesses centered in Hong Kong SAR (HKSAR) and the Chinese mainland. Swire has always been committed to supporting the Chinese mainland's high-quality development. As Premier Li

Keqiang laid out in the *2021 Government Work Report,* an action plan will be drawn up to tackle carbon emissions which we fully endorse. Swire hopes to contribute to, and provide a reference for, the formulation of relevant action plans through our business experience and research. Our studies show that the development of sustainable aviation fuel (SAF) is of utmost significance to the aviation industry's carbon emissions reduction and for China to realise carbon neutrality by 2060. This paper draws on international references, and Cathay Pacific Airways' own experiences to explain the unique challenges of decarbonising air transport and puts forward recommendations for limiting carbon emissions associated with the development of the aviation industry.

As one of the world's leading airlines, Cathay Pacific has implemented various initiatives to mitigate its impact on climate change over the past few decades. This includes continuous improvement of fuel efficiency, the use of carbon offsetting and pioneering the use of SAF. In 2020, Cathay Pacific took a step further with a pledge to achieve net zero carbon emissions by 2050. As existing technologies to improve fuel efficiency reach their limit, and market based mechanisms such as carbon offsetting and trading offer only limited potential in the short to medium term, further operational and infrastructure improvements and new, more radical approaches to aircraft design will be required. Importantly, if the industry's emissions reduction target is to be met, this will also require the widespread adoption and application of SAF.

China is expected to become the world's largest civil aviation market. From being a significant player to the leading player, China’s strategic path in sustainable development is therefore of vital importance to the future of global aviation industry. As a leader in manufacturing and logistics, China’s air transport network plays a vital role in facilitating the flow of goods, direct investment and people. In line with the future trajectory of the country’s aviation activities, China must find an effective solution to reduce carbon emissions stemming from the industry in order to demonstrate its determination to combat climate change.

In addition, the global SAF market is estimated to have an annual potential value of more than RMB640 billion, providing an opportunity for China to harness the value of this market and assume an industry-leading position. Given that the use of SAF is an inevitable trend, China should be forward-looking in terms of formulating supportive policies, cultivating domestic production capacity, improving supply chain development, securing a long term and sustainable supply of SAF and diverging from its dependence on fossil fuels for aviation. Adoption of SAF will also enable airlines to better manage financial risks such as fluctuations in crude oil prices and potential costs from carbon levies. In addition, SAF can contribute to the circular economy and stimulate employment growth in different regions with its wide variety of feedstock, ranging from municipal solid waste, agricultural waste and used cooking oil, to plants farmed on barren land.

At present, the global production of SAF is still in its infancy and accounts for well below 1% of total aviation fuel demand. China has already mastered key technologies in the production and application of SAF and successfully conducted a test flight using SAF as early as 2011. However, its use of SAF is currently limited to testing and one-off flights. Currently there is no public commitment to any long-term production or use of SAF. The policy environment has a significant impact on the development, supply, and application of SAF. Due to the high production cost of SAF at present, policy assistance is key in narrowing the price gap to allow SAF to compete with fossil fuels until scale of production and cost-reduction is achieved. Different policies concerning SAF formulated by different countries result in differing adoption rates. The Chinese government can develop incentives, on both the supply and demand sides, to form a virtuous circle. The government can also draw lessons from international experience with the formation of SAF coalitions around major aviation hubs. China can look for a pilot airport in the Guangdong-Hong Kong-Macao Greater Bay Area to encourage flights departing from the airport to utilise SAF continuously, build a full supply chain of SAF and promote the pilot experience across the whole country, as part of an ambition to become the world’s leader in the development, supply and use of SAF.

Main Paper

Climate change is one of the most pressing global issues. The Paris Agreement aims to limit global warming to well below 2 (and preferably 1.5) degrees Celsius compared to pre-industrial levels. President Xi Jinping announced that China will strive to peak its carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060, demonstrating the Chinese government's responsibility as a major power on this issue. Tackling climate change is a systemic issue that requires vigorous, rapid and coordinated action, as well as joint efforts by policymakers and corporate citizens.

The Swire Group is a highly diversified global business conglomerate established in 1816. Its five divisions include Property, Aviation, Beverages & Food Chain, Marine Services and Trading & Industrial. Having operated in China for 155 years with our businesses centered in Hong Kong SAR (HKSAR) and the Chinese mainland, Swire is fully committed to supporting China's overall development. As a firm supporter and longstanding practitioner of sustainable development, Swire has a clear group strategy and action plans under its 'SwireTHRIVE' programme to address significant, material sustainability challenges including climate change and decarbonisation, as well as water conservation and waste reduction. For example, Swire Properties and Swire Coca-Cola have set science-based carbon reduction targets that have been officially validated by the Science Based Target Initiative

(SBTi). These targets not only include ambitious emissions reductions for our direct operations, but a commitment to engage with our suppliers and customers to drive decarbonisation across the value chain. Both companies have also committed to the Business Ambition for 1.5 °C [12], to show our support for the transition to a net-zero carbon economy as a precursor to the international climate conference (COP26) taking place in November 2021.

The Group's Aviation division accounts for over 90% of its total carbon emissions. As one of the world's leading airlines, Cathay Pacific has undertaken various initiatives to mitigate its impact on climate change over the past few decades, including continually improving fuel efficiency, offering carbon offsets to passengers and pioneering SAF. In 2020, Cathay Pacific further committed to achieving net-zero carbon emissions by 2050. The realisation of this target will be largely dependent on the development and application of SAF.

This paper explains the unique challenges faced by the aviation industry in reducing carbon emissions and the significant role offered by SAF in decarbonising the sector and helping China achieve its carbon neutrality goal. It draws on international experience to make recommendations for future development. Premier Li Keqiang said in the *2021 Government Work Report* that an action plan will be formulated to reach a peak in carbon emissions by 2030. We believe that SAF is an

[12] https://unglobalcompact.org/take-action/events/climate-action-summit-2019/business-ambition

indispensable part of the action required to achieve this peak, and hope that our experience and research can be used as a reference for the formulation of relevant action plans. We welcome the opportunity to provide our thoughts in this regard.

I. Unique challenges faced by the aviation industry in carbon reduction

Although aviation only accounts for 2% of all human-made carbon dioxide (CO2) emissions, it still attracts significant concern and controversy. As aviation increases to meet growing demand, the industry faces unique challenges in achieving its ambition to decarbonise and play its full role in tackling climate change.

1. The inevitable trend of aviation industry development

Since the 1950s, the global aviation industry has grown significantly, with passengers carried growing a few hundred times over. [13] With technological progress and economic development, more and more people are able to enjoy the convenience of air travel, whether for studying abroad, visiting relatives and friends or experiencing different places and cultures first hand. In the past, only the wealthy could afford to fly. Today, many more people can enjoy the benefits brought about by affordable air travel. With continuous economic development, aviation will continue to grow.

[13] https://www.icao.int/sustainability/pages/facts-figures_worldeconomydata.aspx

In addition, air transport is also an irreplaceable mode of transport. High-speed rail is an effective solution to replace certain short-haul flights, especially for China which has a large high-speed rail network. However, about 80% of the carbon emissions from global aviation come from long-haul flights of over 1,500 kilometres. Many long-haul flights involve crossing oceans and continents. So far, there is no alternative mode of transport to meet this demand.

Given that the aviation industry makes important contributions to economic and social development on a long-term basis, its development should not be curtailed by the fight against climate change. But it must grow in a sustainable way to ensure that it can cope with the challenges brought by climate change and benefit future generations.

2. Limitations of existing technologies

Since the dawn of the modern jet age, the aviation industry has substantially improved its fuel efficiency. Since the 1950s, technological advances in internal combustion engine and overall aircraft design have reduced fuel consumption per seat by more than 80%. At present, the improvement of existing technologies has reached a plateau. While there is still room for improvement, incremental improvements will not be sufficient to counter the pace of growth.

The aviation industry has conducted a great deal of exploration in alternative sources of energy, such as electric and hydrogen-powered aircraft. Last year, Airbus unveiled its plan to develop a hydrogen-powered aircraft for commercial operations in 2035. This game-changing technology, whilst exciting news, still has many limitations. Initial designs have limited range, which are insufficient to meet the needs of intercontinental flights, and only carry half the number of passengers as traditional wide-body aircraft, making them commercially disadvantaged. Aircraft usually have a lifespan of at least 30 to 40 years, so unless commercially-viable, low-carbon aircraft can be adopted at scale from 2030, there is not enough time to rely on this approach to achieve China's carbon-neutral target by 2060.

3. The limited effects of carbon offsetting and emissions trading schemes

Carbon offsetting or emissions trading schemes are being used in many parts of the world as a tool to curb the growth of carbon emissions in the aviation industry. Since 2012, the European Union has included the aviation industry in its emissions trading system (EU ETS), covering all flights within the European Union. The Carbon Offsetting and Emissions Reduction Scheme of International Aviation (CORSIA) is a global scheme formulated by the International Civil Aviation Organisation (ICAO) to limit net carbon dioxide emissions from international aviation in order to achieve the target of carbon-neutral growth from 2020 [14].

While these schemes can be used as a temporary measure to offset emissions, they

[14] As COVID-19 has had a significant impact on the aviation industry, the emission data for 2019 will be used in the pilot phase of CORSIA.

do not directly reduce emissions from aviation. As the demand for flights increases, actual carbon emissions will increase accordingly. As a result, it is expected that the share of man-made CO2 emissions from the global aviation industry will increase from 2% to 3% by 2050.

II. SAF is the most promising option to achieve carbon neutrality in the aviation industry

1. What is SAF?

Sustainable aviation fuel, or SAF, is the main term used in the aviation industry to describe non-fossil derived jet fuel. While it was previously more commonly referred to as "bio-jet fuel", the term SAF is now preferred because it more accurately describes the characteristics of this unconventional fuel. "Biofuel" is usually produced from living resources (plant or animal material). However, current technology allows fuel to be produced from other non-living resources such as municipal solid waste or exhaust gas emitted from industrial processes. Furthermore, in order to be labelled "sustainable", the fuel produced must meet certain environmental criteria, such as life-cycle carbon reduction levels, and a non-competitive relationship with food production. Intergovernmental organisations such as the Roundtable on Sustainable Biomaterials (RSB) have set clear sustainability standards for SAF.

Compared with fossil fuels, SAF can have up to 80% lower carbon emissions across its entire lifecycle. Take SAF made from plants: the carbon dioxide absorbed from the atmosphere by plants during growth is equivalent to the carbon dioxide emitted when the fuel is burned. It is important to note that additional emissions are still generated during fuel production from agricultural equipment, raw material transportation and fuel refining. This means SAF cannot be completely carbon neutral.

2. Characteristics of SAF

SAF is made by mixing conventional kerosene (fossil fuel) and renewable hydrocarbons. These fuels can be certified as "Jet A1" or “Jet A” and can be safely used without any modifications to the aircraft or aviation fuel supply infrastructure. SAF can be safely mixed with general aviation fuel in varying proportions, up to the maximum mixing limit. Fuels with these characteristics are called "drop-in” fuels. This allows SAF to be widely and quickly used in existing equipment and infrastructure as long as it is available in large enough quantities.

3. Technical accessibility of SAF

The production of SAF must be a regulated process to ensure that the quality of the fuel is appropriate for its purpose and is safe to use. Currently, the American Society for Testing Material (ASTM) has approved seven production pathways. Each production pathway has different raw material requirements and production technologies, with its own unique challenges and benefits, for example, the availability of sustainable raw materials, capital investment required for equipment, processing costs, and emissions reduction levels. We have included an overview of the approved production pathways in Appendix 1. More production pathways are currently being developed. Once approved, they can provide manufacturers with more options.

III. Cathay Pacific's path to net zero emissions

Cathay Pacific is one of the industry leaders in taking a proactive approach to manage its climate impact. It took a step further in 2020, committing to achieving net zero carbon emissions by 2050. This is a significant step in its sustainable development journey and coalesces its efforts in fuel efficiency improvement, carbon offsetting and SAF usage. However, Cathay Pacific's experience over the years shows that existing technologies cannot lead to a zero-carbon future. Cathay Pacific's zero-carbon commitment is therefore largely dependent on the large-scale application of SAF.

Technology has been the greatest help for reducing aircraft emissions. From 1998 to 2019, Cathay Pacific improved its fuel efficiency by over 20% with investment in new fuel-efficient aircraft and various operational improvements. Cathay Pacific was also the first Asian airline to introduce a voluntary carbon offset programme to enable customers to offset carbon emissions for their flights. Since its launch in 2007, the Fly Greener platform has offset over 300,000 tons of CO2 emissions. But this is far from sufficient to achieve carbon neutrality.

Cathay Pacific has long identified the importance of SAF to achieve substantial emissions reduction and has made important strategic investments. In 2014, Cathay Pacific became a shareholder and board member of Fulcrum Bioenergy, the first airline to invest in the company. Fulcrum is a SAF development company headquartered in the United States, and a global pioneer in developing and commercialising the conversion of municipal solid waste into SAF. Since 2016, Cathay Pacific has delivered 41 Airbus A350 aircraft from Toulouse to Hong Kong with SAF. To date, the project has used more than 200 tons of SAF. In the process, Cathay Pacific gained valuable experience and knowledge about aircraft performance with the use of SAF.

Cathay Pacific has committed to buying 1.1 million tons of SAF from the Fulcrum plant in the United States over a 10-year period. Starting from 2024, the estimated annual uptake will be equivalent to about 2% of Cathay Pacific’s total fuel demand of 2019 operation levels. However, this is far from what is needed given that over half of Cathay Pacific's flights depart from Hong Kong SAR, its home base. Cathay Pacific needs to establish a SAF supply chain in the region. While SAF is increasingly available in Europe and the USA, supply in China has not yet taken off. Cathay Pacific believes the development of a SAF supply chain is not only important for the company to meet its 2050 target, but it is of equal importance for the further development of the civil aviation industry in China and for the country to meet its 2060 carbon neutrality goal.

IV. Strategic significance of SAF for China

1. Significance of emissions reduction in China's civil aviation

As the world's second-largest civil aviation market, China's booming civil aviation industry saw its annual revenue increase to RMB 1 trillion in 2019, with 660 million passenger trips and over 7 million tonnes of air cargo. [15] Civil aviation has made a significant contribution to China's economy. As a key manufacturing and logistics country, air transport plays a vital role in facilitating the flow of goods, direct investments and people, contributing directly to the RMB 9.7 trillion of foreign direct investment and to RMB 15.5 trillion of total exports from China. [16] Looking ahead, aviation will continue to play an important role in China's economic growth. According to forecasts by the International Air Transport Association (IATA), China is expected to become the world's largest civil aviation market by the mid-2020s. [17] By 2037, the number of passengers could triple, and civil aviation is expected to bring in around RMB 1.8 trillion, providing around 6.7 million jobs in China. [18]

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[15] http://www.xinhuanet.com/english/2020-01/14/c_138704443.htm
[16] https://www.iata.org/en/iata-repository/publications/economic-reports/china--value-of-aviation/
[17] http://www.xinhuanet.com/english/2020-01/14/c_138704443.htm
[18] https://www.iata.org/en/iata-repository/publications/economic-reports/china--value-of-aviation/

Given the future growth of China's aviation sector, this poses a challenge in terms of sustainable development, specifically, the likely growth in emissions. China's civil aviation sector emits approximately 100 million tons of CO_2 each year. This level of emissions already ranks second in the world, only after the United States. However, China's per capita aviation emissions are much lower than many countries, about 0.09 tons of CO_2 per person. Corresponding figures for the United States and the United Kingdom are 0.57 and 0.86 respectively. [19] China sees a huge growth potential in aviation activities and related emissions. If China's per capita emissions increase to the level of the United States, its aviation emissions will reach 600 million tons. With the expected substantial increase in both aviation activities and emissions, China needs to find an effective solution to decarbonise the sector to prove its seriousness in dealing with climate change. From being a big player to the leading player, the path taken by China in terms of its own sustainable development is of great importance to the future of global aviation industry.

2. Opportunities in the global SAF market

As early as 2009, the global aviation industry set a goal to substantially reduce carbon emissions by 2050: net carbon dioxide emissions to be reduced by 50% compared with 2005. [20] Due to the limited options available, SAF is becoming

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[19] https://www.carbonbrief.org/emissions-from-chinese-aviation-could-quadruple-by-2050

[20] https://www.iata.org/en/programs/environment/climate-change/

increasingly important. According to International Energy Agency (IEA) "Beyond 2°C Scenario" [21] , it is estimated that global demand for SAF will reach 150 million tons per year by 2060, which is around 60-70% of total aviation fuel demand. The above demand forecast shows that the annual potential value of this market will exceed RMB 640 billion. There will be unprecedented demand for SAF in the coming decades, giving China an opportunity to become a leading player in the industry.

3. Energy security and cost effectiveness

Fuel is usually the largest single operating cost of an airline, averaging at 30%. Fluctuations in crude oil prices will directly affect the profitability of airlines. As potential cost drivers are quite different, using SAF can provide airlines with alternative fuel following a different economic trend. The use of SAF will also reduce dependence on fossil fuels, thus achieving risk diversification. Carbon taxes are also expected to increase in the future. Using SAF would reduce the financial burden related to carbon emissions. In addition, SAF is an inevitable development trend. China needs to have foresight in terms of policies to make a long-term investment in this area, cultivate domestic production capacity, improve supply chain construction, and ensure that SAF can play a role in ensuring wider energy

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[21] https://www.iea.org/reports/world-energy-model#scenarios-in-weo-2020

independence.

4. Promoting circular economy

Certain production pathways of SAF can also promote a circular economy. Multiple production pathways involve the use of different types of waste materials, whether they are municipal solid wastes, agricultural waste or used cooking oil. Even the use of industrial waste gases could generate circular economic benefits: plastics can be produced from ‘recycled carbon’ from the waste gases, instead of solely relying on virgin material or physically recycled plastics.

5. Social and economic benefits

SAF can create new job opportunities through a green economy for different parts of the country. In addition to development around cities and industrial districts for SAF processing plants, some rural areas with land that is unviable for food crops may have a suitable climate for the growth of SAF feedstock. Fuel refining infrastructure is often installed close to feedstock sources, thus creating additional jobs and economic activities.

V. Challenges in mass production and application of SAF

1. Current status of global policy environment, production and application

The policy environment can impose a significant influence on the development and application of SAF. As SAF is currently more expensive to produce, favourable policies will be critical to help close the price gap and enable it to compete with fossil fuels until it can reach economies of scale. Across the world, different policy approaches have resulted in very different SAF adoption rates. Currently, the regions with the highest value incentives are the West Coast of the USA and Europe. Additional information of their policy instruments is provided in Appendix 2. With the support of such active policy making, SAF coalitions are usually formed at major aviation hubs. Such coalitions generally involve different industries or organisations, such as airport authorities, airlines, fuel suppliers, regulators or even local governments. The aim of these coalitions is to bring SAF into use by regular scheduled flights from that airport, and to speed up the process to scale up its usage.[22] A small number of flights are already consistently scheduled using SAF from these airports and show early promise in terms of what could be scalable in future.

Global SAF production is still in its infancy, with volumes well below 1% of total jet fuel demand. Its supply is expected to grow from 2025 onwards and may reach 3 million tons by 2030. However, even so, the total output of SAF is still at quite a low level, accounting for less than 2% of the total demand for aviation fuel. The field is currently dominated by new niche players specialised in SAF production,

[22] About SAF coalitions around the world, Schiphol Airport (AMS) in Amsterdam, Netherlands, is a successful example, with KLM Royal Dutch Airlines being one of its major partners. Many airports on the West Coast of the USA have made similar moves with their fuel suppliers and airlines, including San Francisco International Airport (SFO), Los Angeles International Airport (LAX) and Seattle-Tacoma International Airport (SEA).

but some biodiesel producers and traditional fossil fuel companies are also keen to explore development opportunities, with several already active in the market. Most SAF comes from North America and Europe, with a handful of production facilities in Asia, including in Singapore, Japan and China.

2. Current status of production and application of SAF in China

China has mastered key technologies in the production and application of SAF. A test flight with SAF was conducted successfully as early as in 2011. However, the use of SAF is mainly for testing and one-off flights. Currently there is no long-term commitment for the production or usage of SAF.

Test flights have been particularly important to demonstrate the technical capabilities of SAF to the regulators. They have also served as a good showcase to the Chinese aviation industry that SAF is safe and efficient. After the test flight in April 2013, the Civil Aviation Administration of China (CAAC) issued an aircraft airworthiness certificate to Sinopec to prove its conformance with the necessary quality standards. Additional information of test flights running on SAF in China is provided in Appendix 3.

Biofuel has always been a part of China’s strategic plan to reduce dependence on imported energy and as a way to protect the environment. This strategic direction has been reflected in China's past five-year plans. So far, the strategic plan has only focused on biofuels for road transportation, mainly bioethanol. According to the

13th Five-Year Plan, China has set a goal of achieving 15% of non-fossil energy in primary energy consumption by 2020. As a result, China is currently one of the world's largest bioethanol producers, with an annual output of more than 4 billion litres. However, aviation biofuels have not been included in China's current plan. As China did not place significant focus on the demand for SAF, there is currently limited capacity to produce SAF on a commercial scale in China.

VI. Recommendations for the development of SAF in China

There have been over 300,000 flights using SAF in the past ten years, and SAF has firmly established its position as a safe and technically feasible alternative to traditional aviation fuel. The main obstacles preventing the widespread application of SAF are not technical limitations, but economic ones. The main reason that SAF has not been widely applied is “low demand and low supply”. Small output and higher costs make SAF 2-5 times more expensive than traditional jet fuel. It is obvious that SAF cannot compete with fossil fuels unless there is appropriate policy intervention. Supply chain bandwidth is also an issue. Certain types of sustainable raw materials are in short supply, where limited commercial-scale production facilities are mainly used to produce biofuel for road transport, due to policy requirements or government incentives. As a result, development in SAF supply is further lacking.

Since the development of SAF requires cooperation among many parties, a significant amount of investment, and takes many years, all stakeholders need to be engaged and formulate proactive strategies to increase production capacity. As a result, a stable policy environment is extremely important for the establishment of SAF supply chains. With the establishment of the 2060 carbon neutrality target, China has created a favourable environment to support the long-term prosperity and development of the SAF market.

Many studies have confirmed that, in order to achieve the expected results, a basket of policy interventions is more effective than relying on any single policy instrument. This is best illustrated in the way China achieved rapid progress by closely combining policy support and business drive in promoting and developing new energy vehicles. If policies can exert force both in terms of supply and demand, a virtuous circle will be formed. As demand grows, the SAF supply chain will attract more investment, thus further producing a scaled economy, lowering costs and further expanding demand. To ensure the economic efficiency of SAF, incentives in both supply and demand are required in the medium or short term.

To encourage the development of SAF supply chains, national and local governments may consider supporting SAF research and development, and the construction of demonstration plants by means of tax incentives, subsidies, loans, loan guarantees, direct funding, or public-private partnership. Additional policies can be implemented to de-risk investments into SAF production plants. For example, for foreign companies with experience in building and operating SAF facilities in other markets, favourable conditions can be offered to encourage them to bring their technology and experience to China. In addition, we can refer to the successful experience of China's bioethanol market development and also consider setting production targets.

To increase demand, efforts could be exerted on closing cost differences between fossil aviation fuel and SAF. National or local governments may consider introducing incentives for SAF usage. Due to competitive pricing and additional environmental and reputational benefits, airlines will increase the use of SAF and thus further expand market demand. Existing policy incentive frameworks designed for biofuel usage in ground transport can also be revised to include aviation. Increased incentives for aviation over ground transport should be introduced.

Other policies supporting the development of the SAF market include the adoption of globally recognised sustainability standards to facilitate SAF produced in China to tap into the significant global market. Similarly, policymakers could also encourage users to use existing global SAF accounting standards and to participate in their future evolution and revision.

To facilitate the development of SAF in China, we would suggest selecting certain aviation hubs and establishing local SAF coalitions. The coalition should consist of key stakeholders including airport authorities, fuel suppliers, airlines, and local authorities, with the common goal of making SAF usage a reality for flights departing from that airport on a regular basis. Experience from these pilot sites can then be applied to airports around the country.

We would further suggest selecting the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) as one such pilot site. The HKSAR Government and Cathay Pacific share the same ambitious goal of becoming carbon neutral by 2050. The Hong Kong Airport Authority has also been taking a leading position in the international community in terms of climate change mitigation efforts. Leveraging industrial development, capital flow, technologies and talents in the Greater Bay Area and with government guidance and policy support, we believe Cathay Pacific’s experience in SAF could help GBA become an important forerunner in SAF development in China.

Conclusion

China is well positioned to take a leading role in the global race to net zero emissions to reduce the billions of tons of greenhouse gases added to the atmosphere every year from human activity. Achieving this level of reduction will require a fundamental transformation in every aspect of our lives from energy generation and storage, food production, transportation, manufacturing, the built environment and more.

An enabling policy and regulatory environment for piloting and adopting innovate technologies will be critical for facilitating the transition to net zero emissions. Swire Group companies are testing and adopting a variety of cutting-edge technologies and strategies to improve efficiency and energy savings. Since 2011, Swire Properties has partnered with Tsinghua University through the Joint Research Centre for Building Energy Efficiency and Sustainability to develop and test methods to improve its environmental performance. We support the transition of renewable energy through onsite generation and power purchase agreements. So far, Swire Properties' development in Chengdu and Swire Coca-Cola's Yunnan manufacturing site were powered by 100% renewable electricity.

The common experience of Swire's various business segments, including Cathay Pacific, Swire Coca-Cola and Swire Properties, all show that the guidance and support from government policies are crucial for the business community to achieve its carbon reduction targets. The government can consider encouraging the use of renewable energy, promoting techniques such as smart grids, energy storage battery systems, as well as carbon capture and storage technology to provide more technical tools and institutional networks for carbon reduction projects, expand technological innovation and penetration, and create new financing mechanisms, especially those designed to support net-zero strategies and action plans. Having operated in China for over one and a half centuries, Swire is fully committed to supporting China's path to carbon peaking and carbon neutrality, and to play its part in ensuring that China realises its overall vision for sustainability.

Appendix 1 Seven production pathways for SAF approved by ASTM

Pathway	**Raw material (example)**	**Approved date**	**Mixing limit**
Fischer-tropsch synthetic paraffinic kerosene (FT-SPK)	Biomass energy (forestry residue, weeds and municipal solid waste)	2009	Up to 50%
Hydrotreating esters and fatty acids (HEFA)	Oil-based biomass energy, such as camelina oil, carinata oil, and waste oil	2011	Up to 50%
Hydrotreating fermented sugar-synthesis isoparaffin (HFS-SIP)	Sugar cane, sucrose	2014	Up to 10%
FT-SPK with aromatics (FT-SPK/A)	Biomass energy (forestry residue, weeds and municipal solid waste)	2015	Up to 50%

Alcohol to jet-synthetic paraffinic kerosene (ATJ-SPK)	Agricultural waste (hay, weeds, forestry residue and straw), corn and sugar cane Waste gas emitted during industrial production	2016	Up to 50%
Catalytic hydropyrolysis jet fuel (CHJ)	Soybean oil, jatropha oil, camellia oil, camelina oil, and carinata oil	2020	Up to 50%
Hydrotreating hydrocarbons (HH-SPK)	Seaweed oil	2020	Up to 10%

Appendix 2: Examples of policies supporting SAF

US Renewable Fuel Standard (RFS)

- RFS sets mandatory targets for the use of bio-fuels for refineries and suppliers - 36 billion gallons by 2022. There is also a trading market established for the production of such renewable fuels so that producers can profit from it.

US California Low Carbon Fuel Standard (LCFS)

- LCFS aims to reduce the carbon emission intensity of transportation by 20% by 2030. LCFS supervises fuel suppliers and provides them with carbon value based on the type of fuel they produce. It can be seen as a form of "subsidy for carbon reduction".

UK Renewable Transport Fuel Obligation Act (RTFO)

- RTFO aims to supply 450k litres of SAF each year and aims to meet 12.4% of total fuel needs by 2032. There is a preference for waste-based fuels with specific usage target and a double incentive offered.

EU Renewable Energy Directive (RED)

- RED commits to providing 14% of renewable fuels for the transport sector, including the aviation industry, by 2030. Extra credit is offered for SAF, and certain types of waste derived fuels can also get 1.2 times credit.

Netherlands Transport Energy Obligation Act (HBE Credit)

- HBE mandates companies to increase the share of renewable energy in their fuel supply. The airline industry can choose to take part to benefit from the incentive credits on offer.

Appendix 3 Information of flight tests operated using SAF in China

Date	Airline	Fuel description	Fuel source	Flight description
Oct. 28, 2011	Air China	Fuel refined from 50% jatropha oil	PetroChina	Test flight from Beijing
Apr. 24, 2013	China Eastern Airlines	Fuel refined from palm oil and waste cooking oil	Sinopec	1.5-hour test flight at Shanghai Hongqiao Airport
Mar. 21, 2015	Hainan Airlines	50% SAF refined from waste cooking oil	China National Aviation Fuel Corporation	The first domestic passenger flight Boeing 737-800 from Shanghai to Beijing
May 28, 2016	Cathay Pacific Airways	10% SAF refined from sugar cane	Total SE / Amyris, Inc. (AMRS)	Delivery flight from Toulouse to Hong Kong using SAF
Nov. 22, 2017	Hainan Airlines	15% SAF refined from waste cooking oil	Sinopec	Boeing 787 flight from Beijing to Chicago - the first cross-sea flight using SAF
Feb. 28, 2019	China Eastern Airlines	10% SAF refined from sugarcane	Total SE	Delivery flight of A320neo from Toulouse to Guangzhou